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Selection and Proportion of Aggregates for Concrete

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Economical Selection and Proportion of Aggregates for Portland Cement Concrete

BY ALBERT MOYER

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THE object of this article is to give a practical method which will enable any concrete constructor to make economical use of the best aggregates, so proportioning them as to give the maximum strength and density with a minimum amount of cement. Concrete under discussion is plain and not reinforced, for reinforced concrete, an over-cemented mixture is sometimes necessary, particularly in column construction.

There is a theory that the strength of concrete depends entirely on the adhesion of the cement to the sand and stone. The writer cannot see any tangible reason for this theory as applied to compression strength, for which concrete is designed. Eliminating tensile strength from the mind, it would be possible to make a concrete with a hardening non-cementing material, which could be poured in between the particles of sand and stone so as to fill the voids. While this material would not adhere to the sand or stone, it binds around each particle and thus not only furnishes an arch action, but by its own strength keeps the mass from spreading. Portland Cement not only binds around, but also adheres to each particle of the aggregate. Therefore maximum density is maximum strength in a well balanced concrete of the best materials.

The ideal or theoretically perfect concrete is that in which the best aggregates are scientifically proportioned and graded in size so as to reduce the percentage of voids to the minimum giving the greatest density. It is theoretically possible to so grade the aggregates in regular progression from two to three inch stone down to distinct pieces the size of dust, so that the voids of each progressive volume are filled with the largest size particles that will fit them. Thus a minimum of cement will give a stronger concrete in compression than could be obtained with a larger percentage of cement, using same quality of sand and stone but not properly graded in size.

The ideal and practical, however, are entirely different matters. What the practical user of cement needs is practical information and not a mass of theories which obscure the vision and make it difficult for the "man in the field" to see the few simple laws and underlying principles which, if kept constantly in view, will lead to the best results.

Concrete should be considered as a whole, a definite material designed to meet the requirements of the particular work it has to perform; however, in order to intelligently consider concrete as a whole, we must analyze the function of each of the aggregates.

SELECTION OF THE LARGE AGGREGATES

In discussing the selection of aggregates, I will first deal with the larger size, for the reason that in proportioning the ingredients it is first necessary to measure the voids existing in any given quantity of the largest particles, so as to determine the quantity of mortar necessary to fill these voids. After selecting the best stone or gravel economically obtained in the particular locality in which the work is to be done, the next thought is the grading of this material so as to obtain maximum density, thus reducing the voids and consequently the amount of mortar required to furnish the bond.

Classification of Stone.

As the value of broken stone depends on several conditions, the following classification, read in the order in which they are stated, must be taken merely as a guide:

Trap, Quartz Gravel, Limestone (hard), Granite, Marble, Limestone (soft), Slag, Sandstone, Slate, Shale and Cinders. (N. B.—Poor grades of schist and all micaceous stone should not be used.) Among the conditions which must be taken into consideration are toughness and hardness as being better than stone which may be of a higher classification, but which is more easily fractured. The importance of toughness and hardness as related to strength, increases with the age of the concrete.

Purpose to Govern Selections.

The purpose for which the concrete is intended must always influence the selection. For a very strong concrete, a hard stone without any surface scale is necessary; a rich mortar will not entirely counterbalance a deficiency in the strength of the stone. For a medium strong concrete the hardest stone need not be insisted upon, but rather one to which the mortar will best adhere, such as some of the limestones. For fireproof construction some of the limestones and rocks containing feldspar should be avoided; good boiler furnace cinders have proved best for fire-resisting concrete.

Character of Fracture

For all classes of concrete, stone breaking in cubical form is far better than one breaking in flat layers such as shale or slate, it being almost impossible to ram or tamp such stone into as dense and compact a mass as that breaking in cubical fracture.

Presence of Screening or Quarry Tailings

The size of the stone aggregates depends on the purpose for which the concrete is to be used. For large masses of concrete, 2½ inch stone is usually considered the maximum size, but for 12 inch walls and the usual class of concrete construction, ¾ inch will be found sufficiently large. In considering the selection of broken stone, it must be borne in mind that screenings, quarry tailings, etc., in crushed stone, are not a detriment, as is commonly supposed, but in fact a decided advantage, for the reason that the voids are thus reduced, giving greater density and consequently greater strength; each particle is proportionately as strong as the largest piece of stone from which it came, unless stunned in crushing, as might occur in Granite and Sand Stones. When screenings are used as a portion of the larger aggregates in concrete, the (1-100 in. or less dust) should not be in excess of 10 per

cent. of the volume of screenings, which will pass a $\frac{1}{4}$ inch mesh, as the dust is apt to coat the stone so that the mortar does not come as readily in direct contact with the larger pieces of stone. If, through careful mixing, the mortar does happen to reach every portion of the surface of the larger aggregates, it is from necessity made less rich by the dust; therefore, dust and other particles which will pass through a $\frac{1}{4}$ or $\frac{1}{8}$ inch mesh should be screened out and used as part of the mortar.

Material which is foreign to the stone, such as vegetable mold, scale, or loam, which cling to the surface, will reduce the strength of the concrete. This again is largely a question of careful and thorough mixing. Numerous tests conducted during the last several years by competent engineers have shown that clay in small proportions, not over 15 per cent., when well mixed in the mortar, does not reduce the strength of the concrete; in fact, tests have shown that the strength has been increased. This applies particularly to the leaner mixtures. If carefully mixed, therefore, the clay will not cling to the stone, but will become part of the mortar.

Gravel.

Gravel is often superior to broken stone, being usually found graded from coarse to fine; the roundness of the pebbles lends aid to compactness. It is not likely to bridge and leave holes in the concrete. The percentage of voids is usually less than in broken stone; the quartz pebbles are harder, stronger and less liable to fracture. In this discussion quartz pebbles or other very hard pebbles are referred to; sand stone pebbles are not considered as good as the better grades of crushed stone. The usual argument against gravel is that the mortar is not supposed to adhere as well to the surface as to that of freshly broken stone. This is one of the theories which is practically due to the appearance of the surface to the eye or touch; the adhesion of mortar to lime stone of a smooth surface may be far greater than to sand stone or rougher materials. If roughness was the only requirement for adhesion it would seem impossible to cement together two pieces of glass.

From the standpoint of durability, gravel must be superior to stone for the reason that, by the laws of the survival of the fittest and by process of elimination, nature has supplied us with the most durable. Short time tests for compression strength usually show broken stone concrete to be superior, but long time tests of from six months to a year show gravel concrete on an average to be equal if not stronger.

There is much more to be said on the subject of the selection of the larger aggregates, but the writer believes that the ground has been covered sufficiently for practical purposes.

MORTAR FOR CONCRETE

Mortar for concrete is composed of Portland Cement and sand (preferably coarse, but graded in size), or other fine materials, such as crushed stone, all of which will pass a ¼ inch sieve. Considering the mortar, we have to keep in view the purpose to which the concrete, as a whole, is to be put, so as to judge the necessary strength of the mortar.

Selection of Screenings or Quarry Tailings for Mortar.

In the selection of screenings or quarry tailings, these materials should be from hard, tough stone and free from mica, loam, peaty matter, decayed particles and scale. If used as the entire aggregate for mortar without addition of any sand, 33 per cent. of dust has given good results, as is demonstrated in the manufacture of Architectural Cement Stone, which is now being made in considerable quantities by the use of sand moulds. Limestone screenings graded in size from ¼ inch to fine dust have in numerous instances given greater strength than has mortar made of the same quantity of the best sand. It will also be found that the resulting mortar is denser than a sand mortar, and thus better for waterproofing purposes.

The character of the particles, whether they be flat or cubical in the matter of quarry tailings, has little to do with the dense mortar which is obtained by their use. That the mortar is dense is a practical fact, and as this paper is not a theoretical treatise, I do not feel called upon to go deeply into the theory which will explain these results, excepting to briefly outline that the

density depends on the proper graduation in size of the particles and the percentage of very fine particles and dust present.

There can be no reasonable doubt that with the best material the densest concrete will be the strongest under compression. This idea can be readily grasped if you will eliminate tensile strength from your mind, as concrete is designed almost entirely for compression.

It so happens, however, that quarry tailings or screenings from the best crushed stone when made into briquettes for tensile strength tests, will show far greater tensile strength in long time periods than will the best quality of sand mixed in the same proportions. The writer has in his possession a broken briquette made of one part Vulcanite Portland Cement, 2½ parts quarry tailings which contained 33 per cent. of fine dust, which briquette in two years' time broke at 1000 lbs. per square inch.

Selection of Sand for Mortar.

We now come to the selection of Sand. The value of sand for concrete mortar depends largely on its coarseness, graduation in size of the grains, and cleanliness.

Character of Sand Grains.

The sharpness of the grains of sand has little to do with its value. It has commonly been supposed that sand should be sharp. This, however, is one of the theories which has been exploded. The writer has never seen any tangible reason for such theory. In fact, there are many arguments in favor of coarse, round grain sand. Compactness is what is desired, giving density to the mortar; round grains compact more readily than sharp grains, and the cement will cling to the surface of round grains as well as sharp grains, the character of the surface being identical. Sharp sand is only of value as indicating a silicious sand.

Good sand cannot be easily defined, or an inflexible specification written, as sands of various properties may make equally good concrete. All things being equal, a coarse sand containing a large percentage of coarse particles is far superior to a fine sand in which few coarse particles are present. The full strength of any cement cannot be developed with a sand, all the particles of which are

fine, or so fine as to all pass through a 30 mesh sieve and not graduated in size of particles.

Graduation in Size of Sand Grains.

Economy can be practiced in the matter of the selection of sand. It will nearly always pay the concrete constructor to haul sand even from a considerable distance, paying a higher price, provided he cannot get a sand in the immediate locality of the work, which sand is so graduated in size of grains as to give the greatest density.

Increase of Voids in Damp Sand.

When water is added to dry sand of peculiar characteristics it swells in volume. This is due to the grains being coated with water and by capilary attraction thus pried apart. Thus we have more voids in a cubic foot of some damp sands than we have in a cubic foot of the same sands when dry. Some sands are not well graded in size of particles and will necessarily take up more water than other sand.

Loam, Mica.

Sand containing loam is dangerous for two reasons; one is that loam may chemically react on the Portland Cement causing slowness of hardening, the other is that the loam coats the grains of sand preventing proper adhesion. Sand containing over 5% of mica should not be used.

Clay.

Clay in small percentage will do no harm to sand, providing the sand and cement are thoroughly mixed with a sufficient percentage of water to detach the clay from the sand grains and intimately mix same with the cement, the clay being colloidal in character and of finer particles than the cement, mechanically combines with the cement, producing greater density.

However, it is not safe to use sand containing clay in excess of 15% of the volume of the sand. It is often difficult to determine the difference between certain kinds of clay and loam. Experienced contractors can often judge by feeling; the loam causing a slimy feeling is darker in color, and not as readily washed from the sand particles.

For field work possibly the best test to determine the sand which will produce the greatest density is by means of the water void test properly applied and properly read. Laboratory tests which involve the

use of Portland Cement in determining the sand which will produce the densest mortar is a lengthy procedure.

FIELD METHOD FOR OBTAINING VOIDS IN SAND OF VARIOUS CHARACTERISTICS.

Water tests for Voids.

The void test by use of water should be done in a graduated glass tube. Supply two glass tubes 1½″ to 2½″ in diameter, containing 200 cubic centimeters or over, and marked by a graduated scale divided into cubic centimeters.

Dry the sample of sand to be tested by spreading a thin layer in a pan or over a piece of tin and heating same to a temperature of over 212° F. The reason for drying the sand is to arrive as nearly as possible at an accurate unit of measurement, so that the proportion of cement to sand, which will be described later, may be ascertained. When this sand is cool measure out in the graduated glass tube 100 c.c. of this dry sand; be careful to pour slowly into the tube, jarring the tube while pouring. Level off the top with a flat end stick so as to accurately read the measurement.

In the other glass tube, measure out 100 c.c. of water. Pour the dry sand slowly into the glass tube containing the water and note the height to which the water rises. Also note the number of c.c. of the sand. The sand will not always measure when wet exactly the number of c.c. as when dry, namely 100, as some sands, as previously stated, due to peculiar characteristics, swell in volume when moist or wet.

If 100 c.c. of solid matter had been placed in the glass tube the water would have risen to 200. Therefore, to ascertain the voids, deduct the number of c.c. to which the water has risen from 200. Sand as it comes from the bank or is measured by contractors is always damp or wet; it is assumed that it has swelled to its maximum volume.

If it is found that the sand has swelled in volume then the number of c.c. to which it has swelled over and above 100 must be considered.

As an illustration: 100 c.c. of Cheshire White Quart-

zite, medium, was placed in 100 c.c. of water. It was found that the White Quartzite then measured 114 c.c., showing that it had swelled in volume 14 c.c., thus under working conditions increasing the voids. Therefore, if 114 c.c. of solid matter had been added to 100 c.c. of water, the water would have risen to 214 c.c. It was found, however, that the water only rose 156 c.c., therefore, there is 58 c.c. of voids in the 114 c.c. of sand; divide 58 by 114 and you get 50 8-10% of voids.

For convenience the following table will give the calculations for the percentage of voids:

TABLE No. 1.

100 C. C. Dry Sand Added to 100 C. C. Water.

(C.C. Stands for Cubic Centimeter.)

Water rose to	Sand Swelled in Volume to Following c.c.														
	100 Constant	101	102	103	104	105	106	107	108	109	110	111	112	113	114
	Percentage of Working Voids.														
150	50	50^5	50^9	51^4	51^9	52^4	52^8	53^3	53^7	54^1	54^5	55	55^3	55^7	56^1
151	49	49^5	50	50^5	51	51^4	51^9	52^3	52^8	53^2	53^6	54	54^4	54^8	55^2
152	48	48^5	49	49^5	50	50^5	50^9	51^4	51^9	52^3	52^7	53^1	53^6	53^9	54^3
153	47	47^5	48	48^5	49	49^5	50	50^5	50^9	51^4	51^8	52^3	52^6	53	53^5
154	46	46^5	47^1	47^6	48	48^6	49^1	49^5	50	50^5	50^9	51^4	51^7	52^2	52^6
155	45	45^5	46^1	46^6	47^1	47^6	48^1	48^6	49^1	49^5	50	50^4	50^8	51^3	51^7
156	44	44^5	45^1	45^6	46^1	46^7	47^2	47^7	48^1	48^6	49^1	49^5	50	50^4	50^8
157	43	43^5	44^1	44^6	45^1	45^7	46^2	46^7	47^2	47^7	48^2	48^6	49^1	49^5	50
158	42	42^5	43^1	43^7	44^2	44^7	45^3	45^8	46^3	46^8	47^3	47^7	48^2	48^6	49^1
159	41	41^5	42^1	42^7	43^3	43^8	44^3	44^9	45^4	45^9	46^4	46^8	47^3	47^7	48^2
160	40	40^6	41^2	41^7	42^3	42^8	43^4	43^9	44^4	44^9	45^5	45^9	46^4	46^9	47^3
161	39	39^6	40^2	40^8	41^3	41^9	42^4	43	43^5	44	44^5	45	45^5	46	46^4
162	38	38^6	39^2	39^8	40^4	40^9	41^5	42^1	42^5	43^1	43^6	44^1	44^6	45^1	45^6
163	37	37^6	38^2	38^8	39^4	40	40^6	41^1	41^6	42^2	42^7	43^2	43^7	44^2	44^7
164	36	36^6	37^3	37^9	38^5	39	39^6	40^2	40^7	41^3	41^8	42^3	42^8	43^3	43^8
165	35	35^6	36^3	36^9	37^5	38	38^7	39^2	39^8	40^4	40^9	41^4	41^9	42^4	42^9
166	34	34^6	35^3	35^9	36^5	37^1	37^7	38^3	38^9	39^4	40	40^5	41	41^5	42^1
167	33	33^6	34^3	34^9	35^6	36^1	36^8	37^4	38	38^5	39^1	39^6	40^1	40^7	41^2
168	32	32^7	33^3	34	34^6	35^2	35^8	36^4	37	37^6	38^2	38^8	39^2	39^8	40^3
169	31	31^7	32^4	33	33^7	34^2	34^9	35^5	36^1	36^7	37^3	37^8	38^3	38^9	39^4
170	30	30^7	31^4	32	32^7	33^2	33^9	34^6	35^2	35^8	36^4	36^9	37	38	38^6

In making field tests by the above described method of different samples of sand, use that which shows the least percentage of voids.

Clay or Loam.

Wash 100 c.c. of the sand in 100 c.c. of water by shaking together in a bottle, decant water into a graduated glass tube; again wash sample as before and decant water into the glass tube, stand until settled and read amount of clay or loam.

That the reader may have confidence in the methods above described in ascertaining the characteristics of sand which will produce maximum density, I will describe some of the experiments which I have made.

The use of a graduated glass tube of $1\frac{1}{2}''$ to $2\frac{1}{2}''$ in diameter containing 200 to 250 c.c. might appear to some engineers as being unreliable on account of the small quantities tested and the probable variation of volume. Also the theory of capilary attraction prying apart the grains of sand of certain characteristics might seem to be unsound, but numerous tests seem to bear out this theory. At any rate such peculiar characteristics have been noted by a number of engineers, but the writer has not yet run across any other theory which cannot be explained away. Some say that the head of the water used has different effects, that if a larger amount of water was used instead of 100 c.c., the results would be different. The writer, however, has not found this to be a fact and furthermore it would then be difficult to account for the sand which did not swell at all in volume.

I found, taking the average of one known sand, mixing it thoroughly, drying off the moisture and then measuring out 120 c.c., pouring it slowly into the glass tube and jarring the tube slightly while pouring, making a dozen or more samples and weighing each sample, that the difference in variation was about 2-64ths of an oz.; sufficient accuracy for practical purposes.

I also found by pouring this same sample of dry sand in a glass tube containing 100 c.c. of water, jarring the tube slightly while pouring, that the variation in the volume of sand as nearly as could be read was about $\frac{1}{2}$ c.c.; sufficient accuracy for practical work. Further-

more the water rose to exactly the same height in each instance where the same sand was used.

The voids were calculated as previously described and then checked by means of the specific gravity test.

I have provided the following statement showing these results together with the sieve analysis of the sands tested.

TABLE No. 2.

Following added to 100 c.c. Water: added slowly and jarred.		Weight Sand, Dry.	Sand after settling in 100 c.c. water.	Water rose to	Actual voids in Dry Sand	Working voids in Wet Sand.	Sieves % collected on					
							4	10	20	30	50	Thru. 50
Rockaway Sand, fine, Cow Bay Sand, fine —a few very coarse particles.	mixed 25 c.c. ea. total 50 c.c.	$2\frac{60}{64}$	50 c.c.	132 c.c.	36%	36%	—	.03	$.08^{5}$	$.10^{3}$	$.37^{5}$	$.40^{7}$
Cow Bay Sand	50 c.c.	$2\frac{60}{64}$	51 c.c.	131 c.c.	38	39^{2}	—	$.08^{9}$	$.19^{1}$	$.19^{9}$	$.31^{9}$	$.20^{2}$
Rockaway Sand, fine	50 c.c.	$2\frac{60}{64}$	51 c.c.	131 c.c.	38	39^{2}	—	$.00^{3}$	$.00^{4}$	.01	$.31^{4}$	$.66^{9}$
Cheshire White Quartzite, medium	50 c.c.	$2\frac{34}{64}$	57 c.c.	128 c.c.	44	50^{6}	—	—	.39	.37	$.23^{5}$	$.00^{5}$
Cheshire White Quartzite, 65% coarse, 35% fine mixed	50 c.c.	$3\frac{12}{64}$	52 c.c.	134 c.c.	32	34^{6}	—	.53	$.11^{5}$	$.00^{2}$	$.04^{8}$	$.30^{5}$
Cow Bay Sand, fine particles sieved out	50 c.c.	$5\frac{47}{64}$	50 c.c.	131 c.c.	38	38	—	$.18^{5}$	$.40^{1}$	$.41^{4}$	—	—
Abbott Gully Sand	100 c.c.	$6\frac{3}{64}$	100 c.c.	165 c.c.	35	35	—	$.05^{9}$	$.12^{7}$	$.20^{2}$	$.36^{9}$	$.24^{3}$
Schenectady Brown Sand	100 c.c.	$5\frac{48}{64}$	105 c.c.	164 c.c.	36	39	—	—	$.00^{8}$	$.12^{2}$	$.67^{1}$	$.19^{9}$

To check these results the following calculations were made:

120 c.c. of Cow Bay sand with a preponderance of fine particles, when dry, weighed 7 12-64 oz. This is equivalent to 106 lbs. per cubic foot. If the specific gravity is 2.65 and 120 c.c. of Cow Bay sand weighed 7 12-64 oz., then the calculated percentage of voids is 36. Allowing for the sand having swelled slightly in volume, thus being compelled to calculate the working voids and furthermore, that the specific gravity is assumed, it will be seen that the results obtained by the water test were near enough correct for practical purposes.

Rockaway Sand.

I found that 120 c.c. of Rockaway Sand, which is a fine sea sand of the sieve analysis as shown in table No. 2, weighed 6 54-64 oz., which is equivalent to 102 lbs. per cu. ft. If the specific gravity of Rockaway Sand is 2.65 the calculated voids are 38%, which, allowing for the swelling of the volume of sand, proves the water

test as shown in the table to be near enough accurate for practical purposes.

I mixed up a sand composed of Cheshire White Quartzite, 65% coarse and 35% fine, of sieve analysis as shown in table above referred to; 50 c.c. were found to weigh 3 12-64 oz. As the specific gravity is 2.65, the calculated voids are 32%, which, allowing for swelling of volume, shows the water test to be correct.

Tensile Strength. Rockaway Sand and Various Proportions of Vulcanite Cement.

In order to futher ascertain as to the reliability of the water test for voids in sand as properly determined by the methods above described, I have carried on a series of tests on Rockaway sand. Used this character of sand for the reason that its sieve analysis apparently showed it to be a very poor grade of sand for mortar or concrete.

It will be noted that the water test on Rockaway sand showed 39[2]% of working voids. By reference to table No. 4, this would give us a proportion of 1 part cement, 2½ parts sand. The following statement shows the results of tests and that these proportions are correct.

TESTS OF ROCKAWAY SAND.

PROPORTION	100 c.c. Sand gave a Volume of Mortar of	Average 5 Briquettes Tensile Strength 7 days	28 days	Collected on Sieve.	%
1:1½	125 c.c.	407	524		
				10	.003
1:1¾	120 c.c.	335	445		
				20	.004
1:2	120 c.c.	275	396		
				30	.01
1:2¼	115 c.c.	277	367		
				50	.31[4]
1:2½	110 c.c.	255	334		
				Through	.66[9]
1:2¾	110 c.c.	211	282		
1:3	110 c.c.	181	255		

$5\frac{5}{16}$ oz. Cement figured as = to 100 c.c. which is in same proportion as 94 lbs.=one cu. ft.

You will note that 100 cubic centimeters of sand were used in each instance, and that when the cement in the varying proportions were added, the richest pro-

poroporion, 1 to 1½ caused the volume to expand to 125 c.c., and that in the leanest proportion, 1 to 3, the volume expanded to 110 c.c.

This remained constant up to and including 1 to 2½. The 1 to 2¼ went to 115, showing this to be too rich; the 1 to 2½ being about right.

Tensile strain tests show that this mortar is amply strong, and that a 1 to 3 mix would be entirely too weak.

The difference between the water test above described and the water test which is in the minds of most engineers, is that previously little account was taken of the swelling of the volume of sand and there was no unit standardization of a volume of dry sand. If wet or damp sand is added to water, we cannot arrive at accurate results.

The best sand is that which will require the least amount of cement to produce maximum density, therefore, (taking into consideration the swelling) is that which contains the least percentage of voids. It is assumed that maximum density, the characteristics of the different sands being the same as far as the strength of the sand grains are concerned, is maximum strength.

Water

Water must be clear, odorless and tasteless. If there is taste or odor, the water must be analyzed, the chemist to advise if there is sufficient percentage of any elements present to be injurious to Portland Cement.

Selection of Portland Cement.

Now comes the most important ingredient in concrete, Portland Cement, as it is this material which forms the bond. The other aggregates being usually stronger, upon the uniform strength of the cement depends the strength of the concrete. The selection of stone, screenings, slag, cinders, sand or other ingredients can be determined often by sight or touch, or at least by simple tests. Portland Cement tests require experts of some years' experience; the results of known laboratory tests are merely a guide from which deductions may be made only by the best scientific understanding available. Owing to the variable conditions surrounding such tests, the results cannot be absolute.

Each manufacturer exploits his particular brand as the best cement, some claiming extraordinary fine grind-

ing the criterion, others larger bulk per barrel, others low lime content, others high lime content and hard burned clinkers, etc., etc., and all of them claim the strongest by test, which claims they support by various published test sheets.

Specification for Portland Cement.

In order to select the best grade of cement for very important work, the engineer or constructor should specify the requirements of the Standard Specifications as adopted by the American Society of Civil Engineers and American Society for Testing Materials, as published by the Association of American Portland Cement Manufacturers, copies furnished by any manufacturer of Portland Cement on application. He should then select for purchase the brand that is produced by manufacturers of experience and reputation, as ascertained from engineers, not one but a number, their experience extending over at least five years with several of the well known brands. Having selected one or more brands of the best reputation, he can hold as check against errors or mistakes in manufacture the test described by the specifications above referred to. The brand purchased will necessarily not be the cheapest, but results will undoubtedly prove such brands to be more economical, as less cement may with safety be used; that of the universally best reputation is more liable to be uniform. This method of selecting Portland Cement always gives the user the best material obtainable at the fairest price, making it to the advantage of the manufacturers to produce for the engineer's interest, also offering an incentive to the manufacturer to produce the best product at all times, making improvement as science advances.

PROPORTION OF AGGREGATES.

The previous part of this pamphlet has been devoted to a brief description of what is now almost universally considered as the best ingredients for the manufacture of concrete. The following are some field methods for properly proportioning these ingredients so as to produce maximum density and therefore water-tight concrete.

Please keep in mind that concrete is composed of mortar which binds together crushed stone, pebbles, crushed slag or cinders. If the mortar is not dense, the concrete is not only weak but is not water-tight.

Mortar. We will first consider the methods of proportioning Portland Cement and sand or stone screenings, all passing through a $\frac{1}{4}''$ mesh, which compose the mortar, and then later on consider the methods for proportioning crushed stone or pebbles or the other large aggregates, so that this dense mortar entirely fills the voids, allowing for some excess of mortar, probably about 10%, which will care for any unevenness in mixing or placing.

For field purposes the same methods may be used in proportioning as were described in selecting the sand. A standard for measurement is a necessity. The unit for measurement should be Portland Cement, 94 lbs., one bag, equivalent to one cu. ft., the other aggregates or ingredients figured on this unit. The expression of the proportions as universally adopted is to first state the amount of cement, second the amount of sand or stone screenings, and third the amount of large aggregates; each figure representing the proportions divided by a colon; thus 1 part of cement, 2 parts of sand, and 4 parts of crushed stone, would be shown as 1:2:4.

By reference to various authorities, a barrel (4 bags) of Portland Cement as packed by the manufacturer measures approximately 3.8 cu. ft. The figures in table No. 4 are arrived at on this basis. It can, therefore, be readily seen that if this table is used, or the same calculations are employed, 94 lbs. of Portland Cement may be, for purposes of convenience, considered as a cu. ft. and maximum density result.

I have carried on a large number of experiments based largely on laboratory methods, which experiments tend to show that 3.8 cu. ft. to the barrel of Portland Cement weighing 376 lbs. net, is approximately correct.

If 3.8 cu. ft. weigh 376 lbs., then 100 c.c. will weigh 5 19-32 oz., so if it is assumed that 1 bag of Portland Cement, 94 lbs., is a cu. ft., then 100 c.c. would = 5 5-16 oz.

10% Increase in Volume of Mortar.

Using the calculated voids as per the water test above referred to, and the proportion of cement accordingly, using as a unit of measurement 94 lbs. as assumed to be equivalent to 1 cu. ft., or 100 c.c. as equivalent to 5 5-16 oz., I found that the volume of mortar was entirely dense, economical and in every instance greater than the volume of sand used to the extent of from 10 to 15%; therefore, irregularities in mixing and placing are automatically cared for.

I believe it necessary to go to this lengthy explanation in order that the methods and tables may be thoroughly understood, and being understood the field engineer may arrive at practical results by the use of the instructions which follow:

Avoid using sand composed of a preponderance of one size grains.

METHOD USED TO ARRIVE AT CORRECT PROPORTIONS.

Obtain the voids in sand by means of the graduated glass tube water test as described on Page 10. Use following Table No. 3.

TABLE No.

100 C. C. Dry Sand Added to 100 C. C. Water.

(C.C. Stands for Cubic Centimeter.)

Water rose to	Sand Swelled in Volume to Following c.c.														
	100 Constant	101	102	103	104	105	106	107	108	109	110	111	112	113	114
	Percentage of Working Voids.														
150	50	50^{5}	50^{9}	51^{4}	51^{9}	52^{4}	52^{8}	53^{3}	53^{7}	54^{1}	54^{5}	55	55^{3}	55^{7}	56^{1}
151	49	49^{5}	50	50^{5}	51	51^{4}	51^{9}	52^{3}	52^{8}	53^{2}	53^{6}	54	54^{4}	54^{8}	55^{2}
152	48	48^{5}	49	49^{5}	50	50^{5}	50^{9}	51^{4}	51^{9}	52^{3}	52^{7}	53^{1}	53^{6}	53^{9}	54^{3}
153	47	47^{5}	48	48^{5}	49	49^{5}	50	50^{5}	50^{9}	51^{4}	51^{8}	52^{3}	52^{6}	53	53^{5}
154	46	46^{5}	47^{1}	47^{6}	48	48^{6}	49^{1}	49^{5}	50	50^{5}	50^{9}	51^{4}	51^{7}	52^{2}	52^{6}
155	45	45^{5}	46^{1}	46^{6}	47^{1}	47^{6}	48^{1}	48^{6}	49^{1}	49^{5}	50	50^{4}	50^{8}	51^{3}	51^{7}
156	44	44^{5}	45^{1}	45^{6}	46^{1}	46^{7}	47^{2}	47^{7}	48^{1}	48^{6}	49^{1}	49^{5}	50	50^{4}	50^{8}
157	43	43^{5}	44^{1}	44^{6}	45^{1}	45^{7}	46^{2}	46^{7}	47^{2}	47^{7}	48^{2}	48^{6}	49^{1}	49^{5}	50
158	42	42^{5}	43^{1}	43^{7}	44^{2}	44^{7}	45^{3}	45^{8}	46^{3}	46^{8}	47^{3}	47^{7}	48^{2}	48^{6}	49^{1}
159	41	41^{5}	42^{1}	42^{7}	43^{3}	43^{8}	44^{3}	44^{9}	45^{4}	45^{9}	46^{4}	46^{8}	47^{3}	47^{7}	48^{2}
160	40	40^{6}	41^{2}	41^{7}	42^{3}	42^{8}	43^{4}	43^{9}	44^{4}	44^{9}	45^{5}	45^{9}	46^{4}	46^{9}	47^{3}
161	39	39^{6}	40^{2}	40^{8}	41^{3}	41^{9}	42^{4}	43	43^{5}	44	44^{5}	45	45^{5}	46	46^{4}
162	38	38^{6}	39^{2}	39^{8}	40^{4}	40^{9}	41^{5}	42^{1}	42^{5}	43^{1}	43^{6}	44^{1}	44^{6}	45^{1}	45^{6}
163	37	37^{6}	38^{2}	38^{8}	39^{4}	40	40^{6}	41^{1}	41^{6}	42^{2}	42^{7}	43^{2}	43^{7}	44^{2}	44^{7}
164	36	36^{6}	37^{3}	37^{9}	38^{5}	39	39^{6}	40^{2}	40^{7}	41^{3}	41^{8}	42^{3}	42^{8}	43^{3}	43^{8}
165	35	35^{6}	36^{3}	36^{9}	37^{5}	38	38^{7}	39^{2}	39^{8}	40^{4}	40^{9}	41^{4}	41^{9}	42^{4}	42^{9}
166	34	34^{6}	35^{3}	35^{9}	36^{5}	37^{1}	37^{7}	38^{3}	38^{9}	39^{4}	40	40^{5}	41	41^{5}	42^{1}
167	33	33^{6}	34^{3}	34^{9}	35^{6}	36^{1}	36^{8}	37^{4}	38	38^{5}	39^{1}	39^{6}	40^{1}	40^{7}	41^{2}
168	32	32^{7}	33^{3}	34	34^{6}	35^{2}	35^{8}	36^{4}	37	37^{6}	38^{2}	38^{6}	39^{2}	39^{8}	40^{3}
169	31	31^{7}	32^{4}	33	33^{7}	34^{2}	34^{9}	35^{5}	36^{1}	36^{7}	37^{3}	37^{8}	38^{3}	38^{9}	39^{4}
170	30	30^{7}	31^{4}	32	32^{7}	33^{2}	33^{9}	34^{6}	35^{2}	35^{8}	36^{4}	36^{9}	37	38	38^{6}

Apply following table No. 4, using the proportions as shown in last column opposite the % of voids as ascertained above.

Proportions of cement and sand resulting in maximum density for water-tight mortar.

(Voids to be determined by method described above). Proportions figured on 4 bags=3.8 cu.ft. Proportions stated, 1 bag=1 cu.ft.

TABLE No. 4.

% Voids in Sand.	PROPORTIONS. Figuring actual volume of 1 bbl. cement as packed by Mfgrs. to =3.8 cu. ft. and assuming 1 bag=1 cu. ft.	Proportions to use figuring 1 Bag cement=to 1 cu. ft. Figures are nearest the ¼.	% Voids in Sand.	PROPORTIONS. Figuring actual volume of 1 bbl. cement as packed by Mfgrs. to=3.8 cu. ft. and assuming 1 bag=1 cu. ft.	Proportions to use figuring 1 Bag cement=to 1 cu. ft. Figures are nearest the ¼.
	cu. ft.			cu. ft.	
25	1:3.76	1:3¾	38	1:2.47	1:2½
26	1:3.61	1:3½	39	1:2.41	1:2½
27	1:3.48	1:3½	40	1:2.35	1:2¼
28	1:3.35	1:3¼	41	1:2.29	1:2¼
29	1:3.24	1:3¼	42	1:2.23	1:2¼
30	1:3.13	1:3¼	43	1:2.18	1:2¼
31	1:3.03	1:3	44	1:2.13	1:2¼
32	1:2.93	1:3	45	1:2.09	1:2
33	1:2.85	1:2¾	46	1:2.04	1:2
34	1:2.76	1:2¾	47	1:2	1:2
35	1:2.66	1:2¾	48	1:1.96	1:2
36	1:2.61	1:2½	49	1:1.91	1:2
37	1:2.54	1:2½	50	1:1.88	1:1¾

Proportions of Cement to Screenings or Quarry Tailings.

In the matter of screenings or quarry tailings all passing a ¼″ square mesh sieve, thereby taking the place of sand above referred to, arrive at the voids in the screenings or quarry tailings in exactly the same manner as you arrived at the voids in the sand as described on Page 10, using Table 3, with the exception that a larger diameter graduated glass tube should be used, say about 2½ inches or over in diameter.

Proportions of Crushed Stone or Larger Aggregates.

Next consider the proportions of crushed stone, pebbles or larger aggregates by means of ascertaining the voids. Please keep in mind that the voids are to be filled with mortar as previously described. The Table which gave the proportions of cement to sand composing the mortar has automatically cared for an increase in volume of approximately 10%.

To ascertain the percentage of voids in the larger aggregates, the following table will be a simple means of furnishing this information.

Make a box of such dimensions as will contain 3 cu. ft., box to be 1′x1½′x2. Dry the stone or gravel, heating to over 212° F. Throw the stone into the box loose, level off the top with a straight edge, and having first weighed the box, weigh the box when full. Deduct the weight of the empty box from the gross weight and divide the net weight by 3, which will give the actual weight of 1 cu. ft. Apply following table.

PERCENTAGE OF VOIDS.

Weight per Cubic Foot-lbs	Gravel (Pebbles) without Sand	Sandstone	Limestone medium soft	Limestone medium hard; Sandstone hard	Granite Blue stone Limestone hard	Granite hard Trap medium	Trap hard
75	54	50	52	54	—	—	—
80	51	47	49	51	52	—	—
85	48	43	45	48	50	51	—
90	45	40	42	45	47	48	50
95	42	37	39	41	44	46	47
100	39	33	36	38	41	43	45
105	36	30	33	35	38	40	42
110	33	26	29	32	35	37	39
115	30	—	26	29	32	34	36
120	27	—	—	26	29	31	34
125	—	—	—	—	26	28	31
130	—	—	—	—	—	26	28
135	—	—	—	—	—	—	25

Before ascertaining the voids in stone containing screenings or gravel containing sand, dry by heating, screen out all particles which will pass through a ¼″ mesh sieve; such particles should be figured as a portion of the mortar. Having obtained the percentage of voids in the larger aggregates, the proportion of mortar necessary to fill these voids is thus known.

You are now in possession of the proportions of cement to sand or stone screenings in forming the mortar

and the number of voids in the larger aggregates which will be filled with this mortar. The following Table (Table No. 5) will be a ready means for obtaining the proportions for concrete.

For instance: If the sand you have selected for use requires a proportion of 1 part cement, 2½ parts sand, (1:2½), to produce maximum density of the mortar and your available stone is hard crushed granite 1″ size, and you find a cu. ft. of this hard crushed granite weighs 100 lbs., there will be 43% of voids. Refer to the following table and you will find that the proportions producing maximum density in the concrete to be 1 part cement, 2½ parts sand, and 5¾ parts crushed granite.

The unit for measurement being 94 lbs. (1 bag) of Portland Cement as being equivalent to 1 cubic foot. Proportions of mortar expressed 1 part cement, parts sand (1:1 to 1:4½).

TABLE No. 5.

Voids in Stone	Proportions of Stone expressed in cubic feet											
	PROPORTIONS OF MORTAR											
%	1:1	1:1¾	1:2	1:2¼	1:2½	1:2¾	1:3	1:3¼	1;3½	1:3¾	1:4	1:4½
25	4	7	8	9	10	11	12	13	14	15	16	18
26	3¾	6¾	7¾	8½	9½	10½	11½	12½	13½	14½	15½	17¼
27	3½	6½	7½	8¼	9¼	10	11	12	13	14	14¾	16¾
28	3½	6¼	7¼	8	9	9¾	10¾	11½	12½	13½	14¼	16
29	3½	6	7	7¾	8½	9½	10½	11¼	12	13	13¾	15½
30	3¼	5¾	6¾	7½	8¼	9¼	10	10¾	11¾	12½	13¼	15
31	3¼	5¾	6½	7¼	8	9	9¾	10½	11¼	12	13	14½
32	3	5½	6¼	7	7¾	8½	9¼	10	11	11¾	12½	14
33	3	5¼	6	6¾	7½	8¼	9	9¾	10¾	11½	12	13¾
34	3	5¼	6	6½	7¼	8	8¾	9½	10¼	11	11¾	13¼
35	2¾	5	5¾	6½	7¼	7¾	8½	9¼	10	10¾	11½	12¾
36	2¾	5	5½	6¼	7	7¾	8	9	9¾	10½	11	12½
37	2¾	4¾	5¼	6	6¾	7½	8	8¾	9½	10¼	10¾	12¼
38	2¾	4¾	5¼	6	6½	7¼	8¼	8½	9¼	10	10½	11¾
39	2½	4½	5	5¾	6¼	7	7¾	8¼	9	9¾	10¼	11½
40	2½	4½	5	5¾	6¼	7	7½	8	8¾	9½	10	11¼
41	2½	4¼	4¾	5½	6	6¾	7¼	8	8½	9¼	9¾	11
42	2¼	4¼	4¾	5½	6	6½	7¼	7¾	8¼	9	9¼	10¾
43	2¼	4	4¾	5¼	5¾	6½	7	7½	8¼	8¾	9¼	10½
44	2¼	4	4½	5¼	5¾	6¼	6¾	7½	8	8½	9	10¼
45	2¼	4	4½	5	5½	6	6¾	7¼	7¾	8¼	8¾	10
46	2¼	3¾	4¼	5	5½	6	6½	7	7¾	8¼	8¾	9¾
47	2¼	3¾	4¼	4¾	5¼	5¾	6¼	7	7½	8	8½	9½
48	2	3¾	4	4¾	5¼	5¾	6¼	6¾	7¼	7¾	8¼	9¼
49	2	3½	4	4½	5	5½	6¼	6¾	7	7¾	8¼	9¼
50	2	3½	4	4½	5	5½	6	6½	7	7½	8	9
51	2	3½	3¾	4½	5	5½	6	6½	6¾	7¼	7¾	8¾
52	2	3¼	3¾	4¼	4¾	5¼	5¾	6¼	6¾	7¼	7¾	8¾
53	2	3¼	3¾	4¼	4¾	5¼	5¾	6¼	6¾	7	7½	8½
54	2	3¼	3¾	4¼	4¾	5	5½	6	6½	7	7¼	8½

It will often pay the engineer or contractor to mix together two different sizes of crushed stone or two different sizes of pebbles, say one size of 2″ and one size of ¾″, etc. The proportion of 2″ stone and the proportion of ¾″ stone, or such other sizes as may be convenient, can be ascertained by a simple method as follows:

Make a receptacle which will hold a little over 4 cu. ft., say a piece of 15″ sewer pipe. Measure 3 cu. ft. of the larger size stone and 1 cu. ft. of the smaller size stone, mix well together and place in the receptacle, marking the receptacle on the side the height to which the stone rises. Empty the receptacle and again measure 2 cu. ft. of larger stone and 2 cu. ft. of the smaller stone, mix as before, placing in the receptacle and note on the side the height to which the stone rises. Vary the proportions, measuring in the same manner as before, always adhering to a total of 4 cu. ft. The mixture which produces the least volume in the receptacle will make the densest concrete. The voids in this mixture can be ascertained by the use of Table on page 22.

Illustration:—The best stone obtainable being a hard limestone, which has been selected crushed in sizes of, say, 1½ inch, and ½ inch. These sizes mixed together are found to weigh 120 lbs. per cubic foot (see table page 22), voids are therefore 29 per cent. The available sand in locality requires (by test), 1 part cement, 2½ parts sand, to meet the requirements of the character of work to be done, but by purchasing a sufficient quantity of coarse sand at a point distant to mix with the local sand, a far greater density results; which mixture allows a proportion of 1 part cement to 3 parts sand; therefore, the relative proportion giving maximum density as per above table will be 1 part (95 lbs.) cement, 3 cubic feet of sand, 10½ cubic feet of stone. As there may be conditions due to character or size of particles of stone and sand which would effect the volume, hence density of the whole, it might be well when a reasonable doubt exists to apply same method to the stone with sand and cement added in the determined proportion as was applied in determining a mixture of two or more sands and the proportion of cement to sand. To test the total

mixture of all the ingredients use a piece of 8 or 12 inch sewer pipe, mix wet and tamp, making several test samples. Note proportion of stone used in each sample, use that containing the largest amount of stone which is just short of increasing the volume of concrete. The proportion of cement to sand remains the same, the proportion having been accurately determined by test in the glass tube.

It is altogether a reasonable proposition to state that these proportions made of selected ingredients above described produce a concrete which is actually stronger and more dense than if the concrete had been made of unselected local aggregates. And also allows an immense saving in cement.

The method above described of proportioning the aggregates as opposed to the usual practice of specifying arbitrary proportions regardless of the character of the available ingredients or of the work to be done, has the advantage of offering an incentive to good workmanship. While the aggregates may in some instances prove more expensive, the resulting concrete actually costs less per yard. With expensive aggregates the contractor and foreman will take less chances of waste, and therefore exert more care in mixing and in placing. Arbitrary specifications written by the architect or engineer, which simply state good sand and stone shall be used together with Portland Cement, meeting certain tests, mixed in proportions of 1-2-4 or 1-3-6, as the case may be, may mean a very rich concrete, or again may result in a very lean mixture. Supposing the only available aggregates which can be used in the locality in which the work is to be done, proves to be a stone breaking in flat layers which does not compact so as to give less than 52 per cent. in voids, a 1-2-4 mixture would not give the maximum density, it would be too lean. Then again the aggregates may prove to be a very good grade of stone, which are crushed $\frac{3}{4}$ inch sizes, well graded down to particles which are just short of passing a $\frac{1}{4}$ inch mesh, and the voids are found to be 30 per cent., your mixture is then entirely too rich. These two propositions are sufficient to illustrate the fallacy of arbitrary proportions.

It is a reasonable proposition and one within reach, that the ultimate strength for concrete can be figured within a small margin, provided the character of aggregates are known and the proportion of such aggregates definitely stated, which will give maximum density.

The thought of maximum density should be kept constantly in mind and the idea of a fixed arbitrary proportion eliminated, for the character of the available aggregates will entirely govern the proportions which will give the strongest concrete.

LABORATORY METHOD OF OBTAINING CORRECT PROPORTION OF PORTLAND CEMENT TO SAND OR STONE SCREENINGS FOR MORTAR.

Provide several graduated glass tubes containing 200 to 250 cubic centimeters, with a scale on the side divided into cubic centimeters. Also provide a scale which will balance accurately to a sixty-fourth of an ounce.

In proportioning mortar for actual work, it is convenient to assume 94 lbs. net (1 bag of Portland Cement) as being equivalent to 1 cu. ft. Therefore, in making test samples to determine the percentage of cement to any given quantity of sand which will produce a maximum dense mortar, it is well to take 2 42-64 oz. of cement as being equivalent to 50 c.c.

This is figured as follows: Assuming 4 cubic feet weighs 376 lbs. (the actual is, 3 8-10 cubic feet weighs 376 lbs.) then 100 c.c. weighs .331948 lbs., or 2324 grains, or 5 5-16 oz. or 50 c.c. 2 42-64 oz., so that we can preserve the standard of measurement of 1 bag, 94 lbs., being equal to 1 cu. ft., which for practical purposes is more convenient for measurement.

Weigh several samples of cement of 2 42-64 oz. each (50 c.c., Measure out several samples of sand from 87½ to 150 c.c. each, so that you will have a proportion of cement to sand as follows: 1:1¾, 1:2, 1:2¼, 1:2½, 1:2¾, and 1:3.

The sand should be dried before measuring. To measure the sand accurately, pour the dry sand slowly into the tube, jarring the tube while pouring. Mix 2 42-64 oz. of Portland Cement with each sample of sand thus measured. Add sufficient water to make a mortar which when tamped in the glass tube will not cause any water to rise to the surface. The consistency of the mortar to be about the same as that used in making sand briquettes for tensile strength by the standard methods of testing.

Place a little of this mortar at a time in the graduated glass tube —not over 4 c.c. at one time. Press down hard with a flat-end stick

leaving some space between the flat-end stick and the side of the tube for the expulsion of air. Pack this mortar as tightly as possible in this graduated glass tube. Note the space occupied by each sample. It will be found that the total volume of any one sample will exceed the volume of the sand alone.

The sample containing maximum density will be that which contains (in progression) the largest amount of sand, but has not appreciably increased the volume of mortar. For instance: refer to Page 17, under the heading of "Tests of Rockaway Sand." You will find by this method that the sample containing proportions of 1:3 gave a volume of 110 c.c., 1:2¾ gave 110 c.c., 1:2½ gave 110, and the 1:2¼ gave 115 c.c. Therefore, the 1:2½ is the sample which should theoretically produce maximum density of the mortar. The 1:2¼ would be too rich, and the 1:3 too lean.

The cement having been measured by weight in each instance—the unit of measurement for the cement being 94 lbs., 1 bag of cement assumed to be equivalent to 1 cu. ft., calculated on the actual volume of a barrel of cement as being 3.8 cu. ft.—the quantity of sand being measured and noted for each sample, you are thus in possession of the proportions required for a mortar for use in actual work. This refers entirely to concrete in which maximum density is required; such concrete will be almost impervious to water.

This test should be carried further and samples made of exactly the same proportions but larger in volume, so that tensile strain briquettes may be made to be broken in 7 and 28 day periods. As a matter of interest a sieve analysis should be made of the sand.

Having obtained the volume of mortar produced by each sample and the tensile strength of each sample, you can then determine as to whether a mortar of less density may with safety be used for work which does not require a water-tight concrete.

For instance, in the matter of the test of the Rockaway Sand, if the maximum density was not required a proportion of 1:2¾ might have been used, for it is found that such proportion gave a strength in 7 days of 211 lbs., and in 28 days of 282 lbs., amply strong for ordinary concrete work.

In the matter of screenings or quarry tailings for mortar, all of which will pass through a ¼″ sieve and not containing over 10% of dust—that which would pass through a 100 sieve—you may obtain the proportion of cement to screenings or quarry tailings which will produce maximum density, in the same manner, with the possible ex-

ception that a larger diameter graduated glass tube should be used on account of the shape of the particles of the quarry tailings.

By the method above described the relation of weight to volume is standard, these figures being based on 94 lbs. of cement as being equal to 1 cu. ft. Therefore, it makes no difference whatever if this be actual or not. Thus the variations in different brands of cement are automatically cared for, providing the same brand is used to determine the proportions for mortar as will be used in the actual work. These tests should be carried on with various sands, as there may be two or more sands obtainable in the same locality, one of which might require much less cement than the other and yet obtain maximum density in the mortar, effecting considerable economy on a large job.

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A brand of Portland Cement showing constantly and with uniformity the characteristics of correct composition, soundness, a large percentage of impalpable powder (flour), great strength in long-time periods, coupled with slow setting and rapid hardening, is one which contains a larger percentage of lime and alumina.

The "VULCANITE" Brand manufactured by the Vulcanite Portland Cement Co. contains a greater per cent. of lime and alumina than other cements. "VULCANITE" sets in approximately 7 hrs. 30 min. final—a slow setting cement. It is at the same time rapid hardening, becoming as hard and strong in from 3 to 4 days as other cements are in 7 days, and is even stronger in 7 days than some cements are in 28 days. It continues to gather strength with age.

The cement rock and limestone quarries owned and operated by the Vulcanite Portland Cement Co. are the most uniform in the famous Lehigh Valley region.

The fact that "VULCANITE" is burned at a very high temperature produces a cement of exceptional hardness, making it particularly adapted to sidewalks, pavements and floors, for which it has been preferred for a great number of years.

The fine grinding of intimately mixed, properly proportioned raw materials is of far greater importance than the extra fine grinding of the finished product. The character of grinding is of considerable importance. A mill should be used which will produce the largest percentage of impalpable powder (flour). Do not be misled into thinking one cement is finer than another, containing more flour, because a larger percentage passes through a 200 sieve. There is no sieve manufactured containing over 40,000 meshes to the square inch. This is known as a No. 200 sieve. Portland Cement may be ground so that all the particles will pass through a 200 sieve, and yet all be

collected on a 250 sieve, if we had one that fine, in which event, the cement would be economically useless, as it would take too long to harden. There would be no impalpable powder.

The elutriation test (suspension in air.) is the only one method which will determine the amount of flour present.

Vulcanite contains more flour (impalpable powder) than other cements claiming exceptional fine grinding.

The "VULCANITE" brand has been made under one management since 1895. Only one brand is made, and the mill has been designed to accomplish the results above described.

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CHICAGO — PITTSBURGH

Third Edition

1913

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A Building Material must present an Attractive Surface

Next to the general design of a structure, the character of the surface is probably its most noticeable feature and has the most effect on its appearance. No matter how suitable a material may be in other respects, if it does not present a pleasing appearance in its unfinished condition, or if it cannot be finished in an attractive manner its field of usefulness as a building material is limited. Early experience with concrete seemed to reveal a weakness in this respect. The trouble, however, was not with the material, for there is probably none other so well adapted to all classes of construction, but rather to the fact that proper attention was not given to the placing and finishing of the work.

Surface Treatment a Necessity

The ordinary untreated concrete surface it must be admitted is anything but pleasing in appearance, being a comparatively lifeless surface of a somber grayish color. It makes but little difference what cement, sand or aggregate is used or how they are mixed the untreated form surface is the same, and it is this monotonous similarity in appearance of all untreated concrete surfaces that architects object to so strongly.

Value of Suitable Aggregate lost without Treatment

There may be the greatest difference in color, shape and texture of the aggregates used in two separate surfaces, yet unless they are so treated as to bring out and expose the aggregate they will look exactly alike. It is quite difficult to distinguish an unfinished concrete surface in which ordinary bank gravel is the aggregate, from one in which crushed red granite, for example, is used, but the same surfaces if subjected to any one or a number of different methods of. surface treatment will present a marked and pleasing contrast in appearance.

Color and Texture depend upon Aggregate and Finish

This fact is clearly shown by the colored plates on pages 11, 15, 19 and 23, which are photographic reproductions in color of finished concrete surfaces, identical in every respect, except as to size and character of the aggregate used. By varying the kind, size and proportion of the aggregates, surface finishes of practically any desired color and texture may be obtained, the possibilities being limited only by the number of different aggregates available and their possible combinations. The color is

Reinforced Concrete Viaduct
B. & O. Ry.
Philadelphia, Pa.

obtained from the exposed aggregate, not by adding coloring matter to the mixture. A great variety of finishes may be produced by the use of the common aggregates to be found or easily obtained in nearly all localities, such as limestone, granite or other stone screenings, marble chips and different colored gravels and sands.

Treatment Consists of Removing Film of Surface Mortar

To expose the aggregate the film of mortar that flushes to the surface next the forms must be removed. This may be accomplished either by brushing or washing the surface before it has hardened, or by tooling or sand blasting it after it has thoroughly hardened. The method of procedure is as follows:

Character of Aggregate and Treatment Required Determined by Experiment

Having decided upon the general color scheme, the texture of the surface, and the method of surface treatment to be used, the first step is the making and finishing of small sample surfaces. A limited amount of experimenting with materials available will always prove profitable. The color and texture of the finished surface depends upon the color and size of the aggregates used and the successful production of the desired surface is dependent upon the proper selecting, grading, proportioning, mixing and placing of the materials, as well as the finishing of the surface. Upon determining, by experiment, the size and proportion of aggregates required to produce the desired effect, and the proper consistency of the mix, adhere strictly to them. Take the trouble to measure the materials for each batch of facing material and to gauge them with a measured amount of water. The results obtained will more than justify the small additional time and expense this will entail over the all too prevalent method of measuring materials by wheel-barrow loads and adding water with a hose. In fact, uniform results cannot be obtained unless the work is done as pointed out.

Materials must be Measured

Nicety of Form Construction Unnecessary

A pleasing concrete surface cannot be obtained by nicety of form construction alone. The slightest imperfections and irregularities in the form surfaces are transferred to the concrete, producing unsightly surfaces when left unfinished. Where the surface is to be finished after the removal of the forms, all that is required of the forms is that the face lagging be kept true to surface and the joints be tight. For surfaces that are to be finished by brushing but which are too large to concrete in one day, the forms should be so constructed as to permit of the removal of sections of the face form without disturbing the uprights. This can be accomplished by setting the studs or uprights back a few inches from the face lagging and connecting both by means of cleats and wedges. With this construction only enough lumber for one day's concreting is required, the form being shifted up the next day to receive the next course. The forms for the back of the wall may be constructed in the same manner as described for the face forms, but are usually constructed in the ordinary way and left in place until the work is completed. The face forms should also be well oiled to prevent the concrete from sticking to them.

Special Form Construction saves lumber and requires no extra labor

Buttresses, Panels and Joints make possible the Joining of new and old work

For large areas the introduction of buttresses and panels or the breaking up of the surface by horizontal joints or courses will add greatly to the appearance of the work, the joints simply being indentations in the surface, produced by small triangular, square or rectangular strips of board nailed to the forms. It is extremely hard to join two different days' work so that the joint is not perceptible and unsightly, even when the surface is finished, and the breaking up of the surface as indicated will greatly assist in the concreting if care is taken to end and start a day's work at a course or joint. The results obtained by the use of these strips are clearly shown by the cuts on pages 4, 7 and 9.

Expensive Aggregate used only in Facing Mixture

Where special or expensive materials must be used to obtain the desired surface finish they are used only in the mixture applied as a facing to the exposed surface. The facing mixture as a rule is from 1 to 1½ inches thick, the remaining thickness of the work being composed of ordinary concrete, but the facing and backing must be deposited at the same time so as to make one solid mass in order to insure a perfect bond.

Application of Facing Materials

Concrete blocks, architectural stone and similar work cast in molds where a facing material is used on but one surface should be cast face down. For vertical walls the facing material may be applied to the forms just ahead of the backing which is placed against and rammed into it, or the backing may be placed first and pushed back from the forms with a spade, and the facing material deposited between the backing and the form. Both these methods have been successfully used.

Metal Facing Mold simply constructed

A third and possibly the best method of placing the facing material on vertical surfaces is by the use of what might be called a metal facing form or mold, consisting of short lengths of iron plates 8 or 10 inches wide and about 6 feet long with three angle irons riveted to each plate. The size of the angle required will depend upon the thickness of the facing material desired. An angle should be placed at the center and one about 6 inches from each end of the plate, one edge of which should be provided with handles and slightly flared to assist in depositing the material.

Use of Facing Form

The metal facing form is placed against the wall form with the handles up and the angles tight against the form. The space between it and the back of the wall is filled with ordinary concrete backing and the 1 inch or 1½ inch space between the metal form and the face form is filled with facing material. The metal form is then drawn almost out and after thoroughly tamping the backing against the facing the process is repeated.

Suitable Facing Mixture

For the facing material a fairly rich Portland cement mortar or a rich concrete should be used. Rich mortars have a tendency to check and craze, and for this reason mortar containing more than one part cement

to two parts fine aggregate should not be used. Mixtures of one part cement and 2½ or 3 parts of suitable sand or stone screenings have been found to give excellent results. Where both fine and coarse aggregates are used in the mixture for the facing material a 1:1½:3, 1:2:3 or even a 1:2:4 concrete with cement, sand or stone screenings and crushed stone or screened gravel will give good results. The minimum thickness of the facing material should in no case be less than one inch, and where concrete is used not less than twice the maximum dimension of the large aggregate used.

Concrete Foundation, Indiana Tuberculosis Hospital,
Rockville, Ind.

Brushed Concrete Surface. No special facing.

Brushed Concrete Surfaces

Brushing can only be done on Green Concrete

Where the finish is to be obtained by brushing, the forms must be removed from the work as soon as possible and the concrete surface brushed while still green. It is not possible to state how old work should be before removing the forms and brushing the surface. This will depend upon a number of conditions: the character of the work, cement

Residence,
Evanston, Ill.

Brushed Concrete Surface.
Special facing.

and aggregate used, consistency of the mixture and very much upon the weather conditions. As a rule, in hot weather the forms should be removed the next day and the surface brushed, but in cold weather the facing form cannot be removed so soon, several days or perhaps a week being required for the concrete to obtain the necessary hardness and strength. Care must be taken that the brushing is not started too soon as little particles of aggregate will be removed resulting in a pitted and unsightly surface. On the other hand, the longer the surface stands before being brushed the more brushing it will require to remove the film of

mortar that has flushed to the surface. The brushing should be started just as soon as it is possible to do so without removing particles of aggregate. The time required for sufficient hardening can only be determined by experimenting with the particular surface.

An easily made Wire Cloth Brush is best

A brush about four inches wide, made by clamping together a sufficient number of sheets of wire cloth, has been found to be more effective and cheaper than the ordinary wire brush for brushing green concrete surfaces. An ordinary scrubbing brush with stiff palmetto or other fibre bristles will answer if the surface is not permitted to get too hard. The free application of water during the brushing will materially assist in the work.

Detail of residence on opposite page.

Brushed Concrete Surface. Special facing.

Acid Wash needed to finish treatment

After the entire surface has been brushed the appearance of the work can be improved by washing with a diluted solution of acid applied with a brush. While wet with acid the surface should be quickly worked over with an ordinary scrubbing brush and the acid immediately removed with clear water applied through a hose. It is important that the surface be thoroughly washed after the acid treatment as otherwise it will have a mottled, streaky appearance. This final acid treatment thoroughly cleans the aggregate, thereby intensifying the color and assists greatly in giv-

ing the surface a uniform appearance, especially on large surfaces where different sections have been brushed at different times.

Strength of Acid Solution

A solution of one part commercial muriatic acid to 2 or 3 parts of clean water should be used on surfaces in which standard Portland cement is used, and a sulphuric acid solution of the same strength when white Portland cement and white aggregates are used in the facing mixture.

Description of Surfaces shown in color

The color plates on pages 11, 15, 19 and 23 in this booklet are photographic reproductions in natural size of brushed concrete surfaces in which Universal Portland cement and different stone screenings were used. All the surfaces are of a 1:2½ mixture, except No. 6 which is of a 1:3 mixture.

Plate No. 1 on page 11 illustrates the results to be obtained by the use of a facing mixture composed of Portland cement and ordinary ¼″ yellow marble screenings, from which the material passing a No. 8 sieve has been removed.

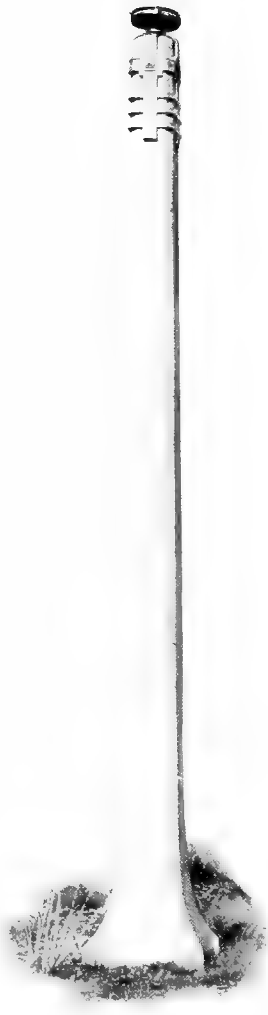
Plate No. 2 is identical in every respect to No. 1 except that red granite was used instead of yellow marble.

Plate No. 3 on page 15 shows a surface in which black marble was used. The aggregate all passed a ½″ mesh and was retained on a ⅛″ mesh, but owing to the manner in which it crushes, was mostly of one size.

Plate No. 4 is identical to No. 3 except that equal parts of black and white marble were used.

Plate No. 5 on page 19 shows the results obtained with ordinary lake shore gravel screened through a ½″ mesh and retained on a ¼″ mesh.

In the surface shown in Plate No. 6 the aggregate used consisted of a mixture



Lighting Pillar, Lincoln Park, Chicago.

Brushed Concrete Surface, treated with acid. Special facing.

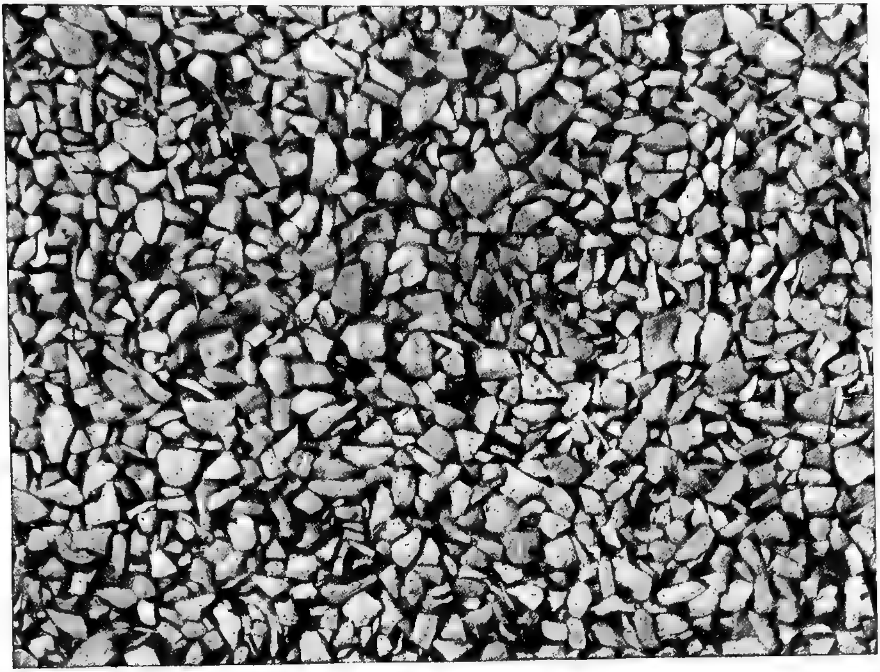


Plate I — ¼″ Yellow Marble

Plate II — ¼″ Red Granite

of equal parts of black and white marble, red granite, and the same materials as were used in the surfaces shown in Plates 1 and 3.

Plate No. 7 on page 23 shows a surface composed of the same materials as in Plate No. 6 except that the aggregate all passed a No. 8 sieve.

Plate No. 8 shows a surface composed of screened Torpedo sand passing a No. 8 sieve.

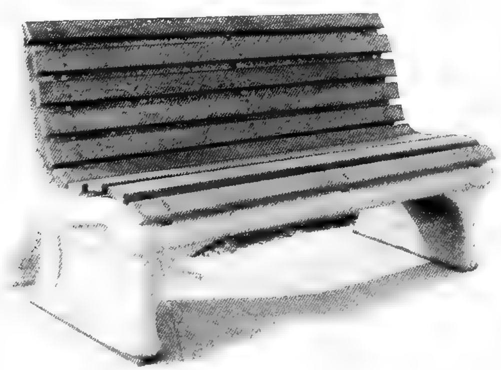
The concrete surfaces represented by these colored plates together with many others, may be seen at the offices of the Universal Portland Cement Company, 115 Adams Street, Chicago, Illinois.

Cheap Aggregates used with good results

A good grade of limestone makes a very acceptable white aggregate to use in place of the more expensive white marble, and both black granite and trap rock make good substitutes for black marble where a dark surface such as that shown in Plate 3 is desired. By varying the size of the aggregate used, a surface finish of practically any desired texture may be obtained, the size and grading of the aggregate producing nearly as much variation in this respect as its color does in the appearance of finished surfaces. Fine, well graded aggregates produce a comparatively smooth even grain surface of a solid uniform color, whereas large one-size aggregate makes a much rougher surface of not such a solid uniform color.

The Field of the Brush Treatment

This method of finishing exposed concrete surfaces by brushing may be used for all types of construction. It is suitable for finishing the surface of concrete blocks and architectural stone where the forms can be removed immediately, as well as for monolithic work, such as foundations, buildings and bridges, where the forms must be left in place for a short time. The cuts shown on pages 7, 8, 9 and 10, give some idea of the variety of actual construction where a desirable surface finish has been obtained by brushing.



Concrete Park Bench,
Lincoln Park, Chicago.

Rubbed Concrete Surfaces

By removing the forms from the work when the concrete is a day or two old and rubbing the surface with a brick of carborundum, emery, concrete or soft natural stone, a desirable surface finish may be obtained. **Method of Rubbing Down Green Surfaces**

Retaining Wall, C. & N.-W. Ry.,
Evanston, Ill.

Rubbed Concrete Surface. Special mortar facing.

With this method of surface treatment the best results are obtained where a facing mixture containing little or no coarse aggregate is used, or where the coarse material has been well spaded back from the face of the work. In connection with the rubbing, a thin grout composed of cement and sand should be applied to the surface, well rubbed in, and the work afterwards washed down with clean water. The grout is used simply to fill surface imperfections and should not remain as a film on the surface.

Rubbing Widely Practiced

This method of treatment erases form markings and produces a comparatively smooth surface of uniform color much superior to that obtained by the all too prevalent method of painting with a grout, which almost invariably crazes, cracks and peels off. During the past two years a large amount of concrete work has been done in Chicago and its suburbs by the Railroad Companies in connection with their track elevation and the exposed surfaces of concrete abutments and of miles of retaining walls have been given a suitable finish by this method. The present appearance of the work indicates that it makes a very acceptable cheap way of finishing work of this character. The exposed surfaces of the structures shown on pages 13 and 14 were finished in this manner.

Monolith Concrete Station,
C. & N.-W. Ry.,
Evanston, Ill.

Rubbed Concrete Surface treated with cement stain. Special mortar facing.

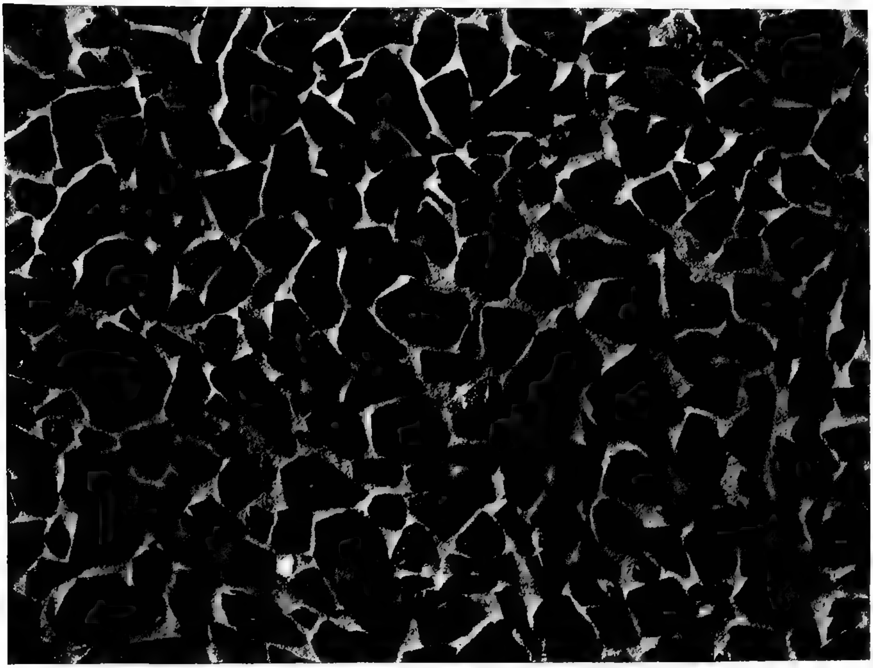


Plate III — 1/8″ to 1/2″ Black Marble

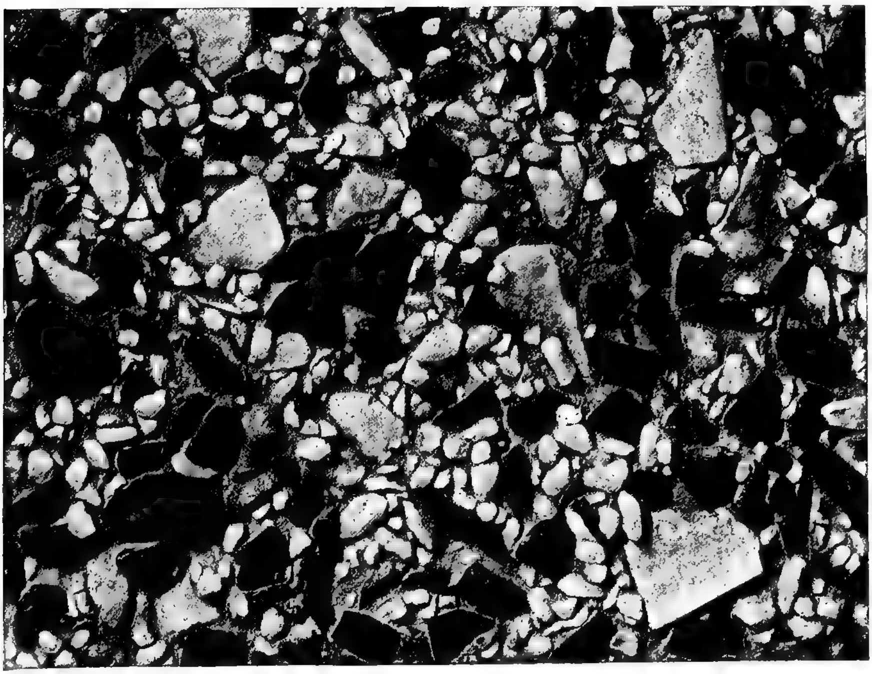
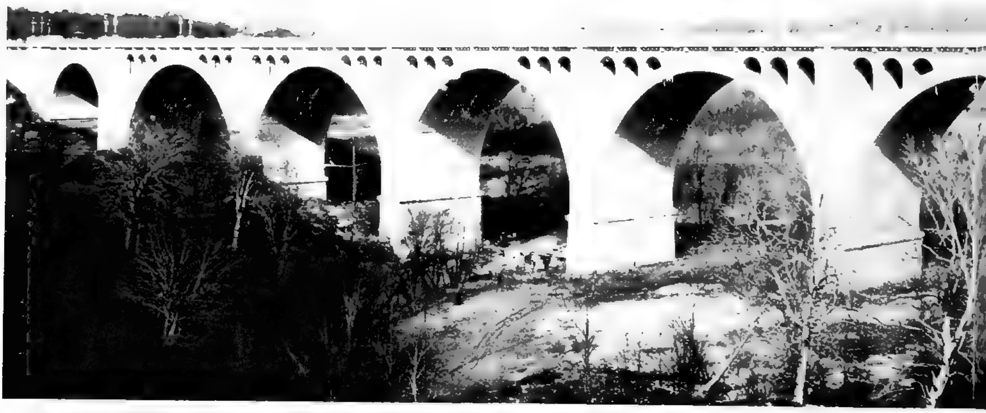


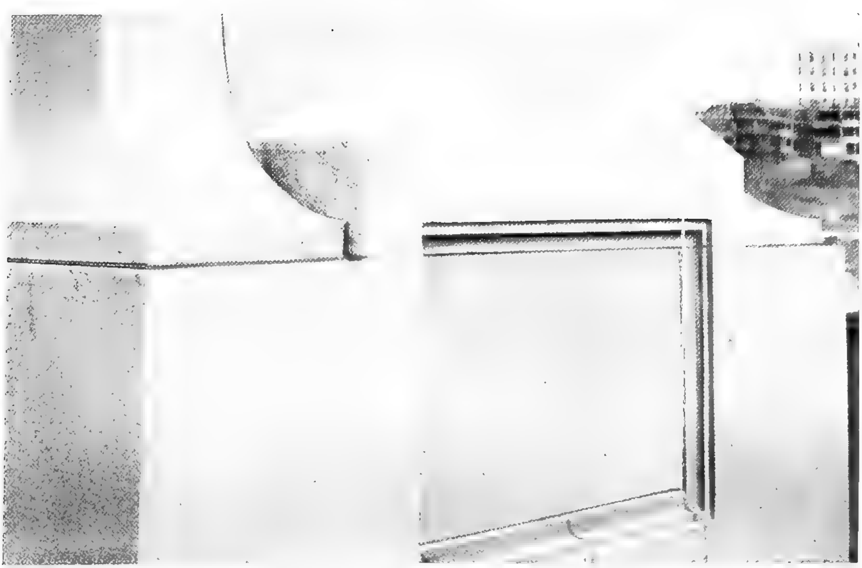
Plate IV — 1/4″ Black and White Marble



Detail of bridge above.

Connecticut Avenue Bridge, Washington, D. C.

Bush-Hammered Surface.



Detail of finish of bridge above.

Tooled Concrete Surfaces

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Concrete surfaces may be finished by tooling by any of the methods and in any of the styles employed for dressing or finishing natural stone. Where the surface is to be tooled the best results are obtained when a facing material with comparatively small sized aggregate is used, as it is hard to dress and to obtain uniform results on surfaces where large angular hard stone is encountered. It is not necessary to construct the forms so they may be taken down in sections as was described for brushed surfaces, for the concrete should as a rule be thoroughly hardened before tooling, especially if sharp edges and surfaces of a fine uniform texture are desired.

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If the forms are removed when the concrete is two or three days old and the surface is dressed with a hand pick or stone ax, a comparatively large amount of material is scaled off, the finished surface being of a coarse texture similar in appearance to rough dressed natural stone. Some variation in the appearance of the finished surface can be obtained by the manner in which the tool is handled. By striking a perpendicular blow no lines or marks are left in the surface, whereas with a glancing blow, tooth marks are left which can be made parallel to each other or at various angles.

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A very desirable finish has been obtained on numerous bridges, buildings and other structures where suitable facing material has been used, by bush hammering the surface, either by hand or with a pneumatic tool. The best results with the bush hammer are obtained on thoroughly hard concrete surfaces. Where a finish of a comparatively smooth uniform texture is desired, especially on surfaces where no facing material or one composed of large aggregate has been used, the concrete should be at least two months old before bush hammering. Otherwise the particles of coarse aggregate are apt to be dislodged instead of cut and exposed, resulting in a pitted instead of a smooth uniform surface. Nine-pound hammers having as many as 36 points on a cutting face four inches square have been used, but the most satisfactory results are apparently obtained with lighter hammers having fewer points. In one case a better finish was obtained and at a less cost by substituting a hammer having 16 points for one having 36 points, and a popular hammer for finishing concrete surfaces is one weighing about three pounds and having but 4 points.

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Plate V **¼″ to ½″ Lake Shore Gravel**

Plate VI **¼″ Black and White Marble and Red Granite**

xample of Bush Hammering Washington Bridge

The exposed surfaces of the concrete stone used in the construction of the Connecticut Avenue Bridge, Washington, D. C., shown on pages 16 and 17, were faced with a 1:3 mixture of Portland cement and ⅜-inch crushed granite screenings and finished by bush hammering. The work was done by hand using patented hammers and skilled labor, and a very good finish closely resembling dressed granite was obtained. The cover of this booklet shows one of the four concrete lions on the approach to the bridge. The concrete pedestal supporting the lion, shown in greater detail on page 17, has a bush hammered surface and the finish obtained here is representative of that of the entire structure.

Sand Blasted Surfaces

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A finish of very much the same texture and appearance as that obtained by brushing while green may be obtained by sand blasting a thoroughly hardened concrete surface. Any pronounced ridges or irregularities in surface, formed by cracks or open joints in the forms should

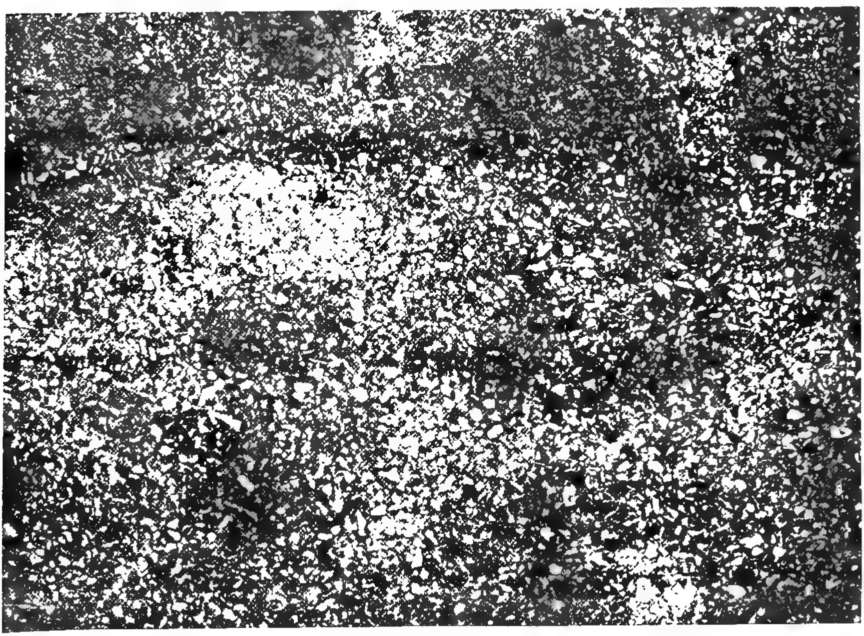
Monolithic Concrete Station, C. M. & St. P. Ry., Columbus, Wis.

Sand Blast Finish. No special facing.

be removed by tooling and any pointing that may be necessary should be done several days before the surface is sand blasted. In attempting to remove these ridges with the sand blast, the surface on either side is apt to be cut too deep and depressions in the surface intensified or made more prominent instead of being erased. Where it is possible to do so the strips nailed to the forms to make molding, joints and courses, should be left in place while the surface is being sand blasted. Otherwise the sharp angles and edges will be rounded off in a rough and unsightly manner. Leaving the area protected by the strips unfinished adds to, rather than detracts from the appearance of the work, as is to be noted in the cut shown on page 7. When sand blasting near the intersection of two surfaces a board should be held against one in such a manner as to protect the angle or edge, as the case may be, if a clean cut line is desired.

Sizes of Nozzle and Sand Recommended

Upon a smooth, dense, thoroughly hardened concrete surface a 3/8-inch nozzle may be used, but under ordinary conditions 1/4-inch or even 1/8-inch nozzles have been found to give the best results. A clean, sharp, thoroughly dried silica sand or crushed quartz is most effective for sand blasting, and for use with a 1/4-inch nozzle the sand should be screened through a No. 8 screen, and through a No. 12 when a 1/8-inch nozzle is used. The best results are apparently obtained on a thoroughly hardened



Detail of finish on station, page 20.

concrete surface at least a month old, and for such work a nozzle pressure of from 50 to 80 pounds will be required.

The surface of the concrete Station shown on page 20 was finished by sand blasting and the cut on page 21 shows in detail the character of the finish obtained.

Colored Concrete Surfaces

Aggregate Should Preferably Furnish Color

The most satisfactory concrete surface of a given color and texture is obtained by properly finishing a surface faced with a mixture composed of cement and an aggregate of the proper size and color. Such a surface may be considered as permanent, will not deteriorate, scale, fade or require renewing. When aggregates of the required color are not available, or for any reason it is not possible to obtain a surface of the desired color in this manner, satisfactory results may be obtained by what might be termed body coloring and surface coloring.

Method of Body Coloring

In body coloring the coloring matter is thoroughly mixed with the materials used in the facing mixture, thereby producing a facing of a uniform color for its entire thickness. The color matter can be used either in a dry form or as a paste. When used dry the most satisfactory results are apparently obtained when the coloring matter is first thoroughly mixed dry with the cement, and this mixture mixed dry with the aggregate before adding any water. Some prefer, however, to mix all the materials together dry in one operation, while others prefer to add the coloring matter to the mixing water.

Mineral Pigments Necessary

The ingredients of cement have a strong and generally injurious chemical action upon most of the ordinary pigments. Those of vegetable origin are most susceptible to this action and for this reason for body coloring only mineral colors should be used. Owing to the danger of impairing the strength of the mixture, only a limited amount of coloring matter can be safely used, and it is better to obtain the desired shade by the use of a small amount of a strong though high priced color rather than by the use of a large quantity of a cheap, weak coloring matter. About 5% by weight (of the weight of the cement) is maximum amount of coloring matter that can be safely used. Owing to the fact that the number of pigments available is limited, and that but small amounts of these can be used, the different colors and shades to be obtained by body coloring are comparatively limited. The following table taken from "Cement and Concrete," by L. C. Sabin, shows the colors obtained by the addition of various amounts of different coloring materials.

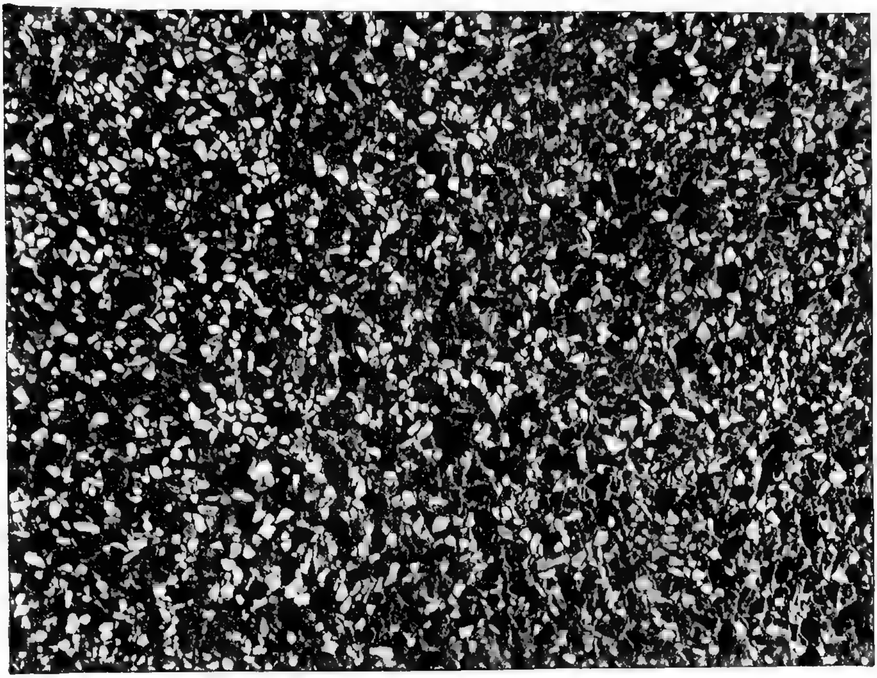


Plate VII   1/8″ Black and White Marble and Red Granite

Plate VIII   1/8″ Screened Torpedo Sand

COLORED MORTARS

Colors Given to Portland Cement Mortars Containing Two Parts River Sand to One Cement

Dry Material Used	Weight of Dry Coloring Matter to 100 Lbs. Cement.				Cost of Coloring Matter per Pound (cents).
	½ Pound	1 Pound	2 Pounds	4 Pounds	
Lamp Black...	Light State..	Light Gray ..	Blue Gray	Dark Blue Slate.... .	15
Prussian Blue..	Light Green. Slate......	Light Blue Slate......	Blue Slate	Bright Blue Slate......	50
Ultra Marine Blue	....	Light Blue Slate......	Blue Slate	Bright Blue Slate......	20
Yellow Ochre..	Light Green	....	....	Light Buff...	3
Burnt Umber..	Light Pinkish Slate...	Pinkish Slate	Dull Lavender Pink........	Chocolate....	10
Venetian Red.	Slate, Pink Tinge.....	Bright Pinkish Slate	Light Dull Pink........	Dull Pink ...	2½
Chattanooga Iron Ore....	Light Pinkish Slate..	Dull Pink...	Light Terra Cotta.......	Light Brick Red.......	2
Red Iron Ore.	Pinkish Slate	Dull Pink...	Terra Cotta...	Light Brick Red.......	2½

Surface Colors Apparently Successful

In surface coloring the coloring material is applied as a thin film or coating on the surface after the concrete has hardened. The results to be obtained with ordinary oil paints when used in this manner are questionable and they should not be used upon concrete surfaces, but there are a number of specially prepared paints, cement stains and cement coatings on the market that apparently give splendid satisfaction.

Miscellaneous Surfaces

A Desirable Surface Obtained by Special Mixture

A method of finishing exposed concrete surfaces has been developed by the engineers of the South Park Commissioners of Chicago, and successfully used by them in the erection of large monolithic concrete buildings. By using a comparatively lean dry mixture for the entire thickness of thin walls and as a facing for heavy walls a concrete surface is obtained which does not take the imprint of the form imperfections and which requires no further treatment after the removal of the forms. For this work they use a mixture composed of about one part cement, one and one-half parts sand and four and one-half parts crushed limestone screenings passing a one-half inch screen, and from which the fine material has been removed by rescreening through a quarter inch screen. The stone is all of approximately one size, being about one-quarter inch material. The concrete is thoroughly mixed so dry that no mortar flushes to the surface when it is well rammed into the forms which are constructed in the usual manner.

Success of Above Method

The resulting surface has a rough porous texture of a uniform, soft, cement-gray color. Contrary to what might be expected of a surface which absorbs considerable moisture, work that is six years old shows no evidence of injury from frost. It is also possible to obtain sharp clean cut lines for architectural details and moldings, and a surface which remains remarkably free from discoloration due to efflorescence.

The Administration building facing page 3 shows the type upon which this method of surface finish has been used, and the character of the finish obtained.

Colored Clay Inserts

In addition to the methods already described, very effective results can be obtained by imbedding colored clay tile or mosaics in concrete surfaces in such a manner as to form patterns and designs. Any one or a combination of different methods can be used in placing the tile. By arranging them in position on a pallet and depositing a cement mortar or concrete around the tile a thin concrete slab containing the desired pattern can be cast and this slab inserted in a space of the required size and depth left in the concrete surface. The tile can also be placed against the forms and the concrete placed directly back of them. This is best accomplished where an elaborate design is worked out by first gluing the tile to a piece of tough, thin paper which in turn is glued or otherwise fastened in the proper position to the forms. Still another method is to set the tile, piece by piece, in recesses of the required depth and outline left in the surface of the wall.

The recesses in the concrete surface for the tile are formed by nailing boards of the required thickness and outline on the inside of the forms. These pieces of board should remain in the wall after the removal of the wall form and should be left in place until the concrete surface is given the desired finish.

A good example of decoration by inlaid tiles is shown on page 30.

Surface Finish For Concrete Blocks

Blocks Susceptible to All Foregoing Treatments

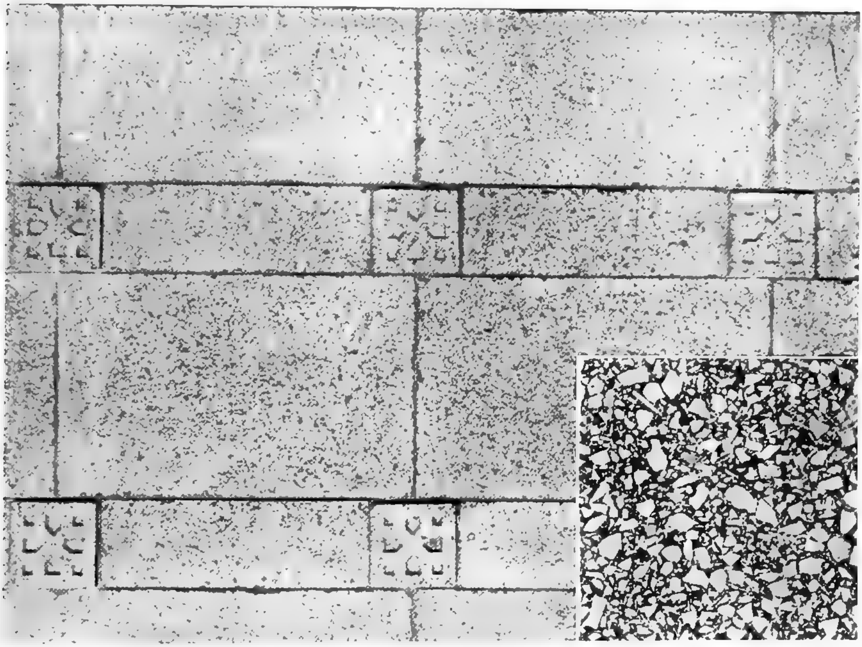
For but a fraction of the cost of quarrying, dressing and preparing a natural stone for use, a suitable concrete block can be manufactured, which if given a proper surface finish will be as acceptable for any class

Office Building,
Buffington, Ind.

of construction as the more expensive natural stone. All of the methods described are especially well adapted for use in finishing the exposed surface of concrete building blocks and architectural stone, where it is possible to remove the forms, and brush, tool, rub or sand blast the surface at the most opportune time.

Blocks with Ground Face

The blocks shown in cuts on this page were faced with a 1:2 mixture of cement and limestone screenings, and finished by placing them on



Detail of finish on office building, page 26.

a revolving metal disk covered with wet lake sand where the exposed face was ground down to a smooth uniform surface. By this effective cheap method a concrete block of a distinctly pleasing and unusual appearance was obtained.

True "Rock face" Blocks

A novel method of facing concrete blocks has been developed at the State Hospital, Yankton, So. Dak., and the blocks have been extensively used for the construction of many large buildings there, and at the State Hospital at Elgin, Ill. The blocks can be correctly called "rockface" as they are faced with thin pieces or chips of granite of irregular shapes and sizes, split by hand from larger pieces.

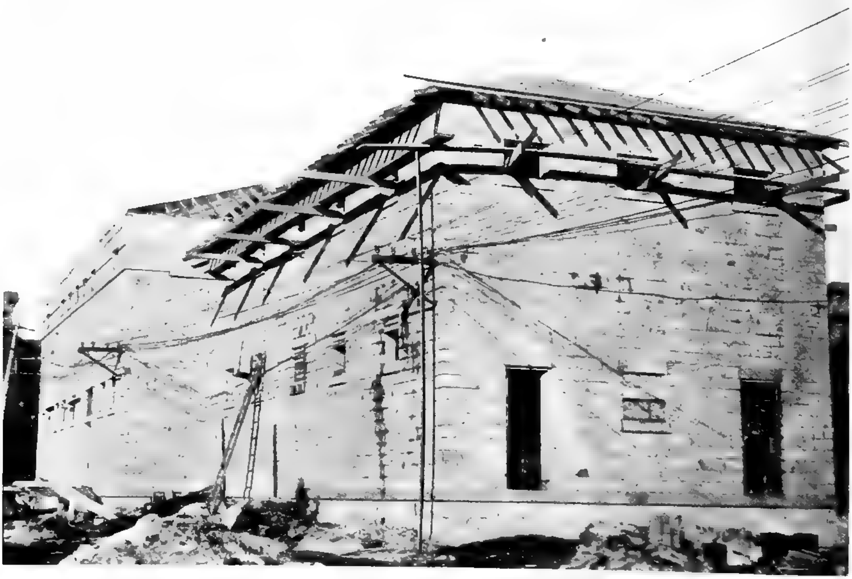
These concrete blocks are cast face down in long gang molds having metal sides separated by metal plates. These plates are cut to a size to

conform to the desired section of the block, and are so spaced between the sides as to make blocks of the required length. The metal forms are placed on long boards of the required width which serve as pallets.

Special Block Mold and Its Use

A layer of sand about one-half inch thick is first spread over the bottom of the form, and upon this sand the stone facing is laid. No special care is taken in arranging the stones except that they are placed as close together as is possible without overlapping. A rich mortar consisting of one part cement and one part sand mixed very wet is then poured into the forms, sufficient mortar being used to practically cover the stone. Immediately after pouring the mortar the forms are filled with ordinary concrete mixed about one part cement to two and one-half parts sand and five parts crushed stone or screened gravel. The blocks are left in the forms until the following day when they are removed, stored and cured as is customary with ordinary concrete blocks and without further treatment are ready to be placed in the wall.

The cuts shown on this and the opposite page will give some idea of the results to be obtained by this method of facing concrete blocks.



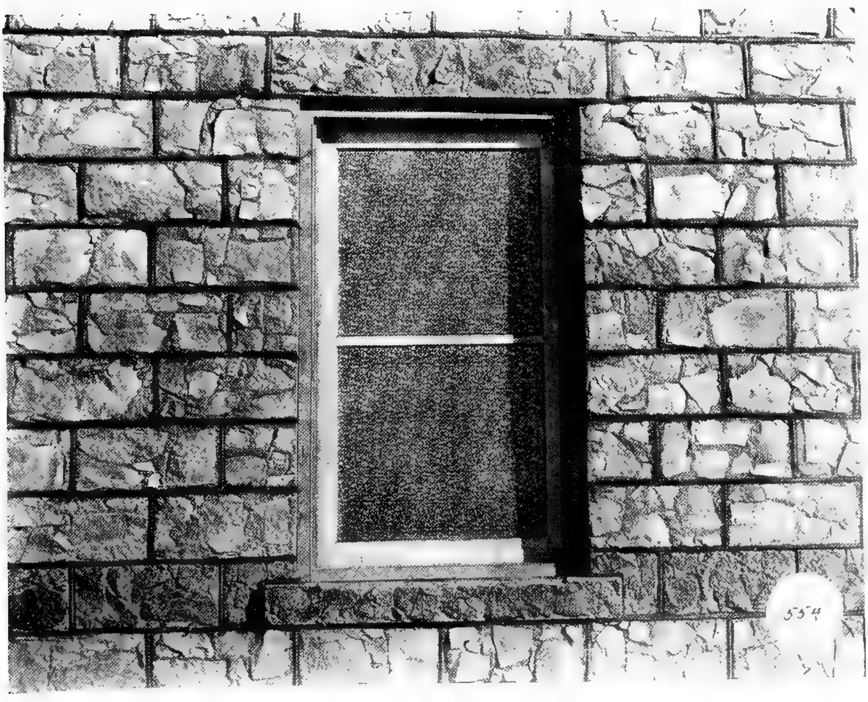
Concrete Block Cold Storage Building, State Hospital,
Elgin, Ill.

Blocks Faced with Natural Stone.

Cost of Finishing Concrete Surfaces

Owing to the fact that but little attention has been given heretofore to the proper finishing of exposed concrete surfaces, there is comparatively little reliable data available concerning the cost of this class of work. Records of the actual cost of finishing surfaces by the methods enumerated have been kept in but few cases and the estimates furnished for doing such work show a wide variation.

The additional cost of a finished, as compared with an unfinished concrete surface, is made up of two separate items; the cost in place, of the special facing mixture, and the cost of finishing the surface after the forms are removed. Where the work is carefully planned beforehand there should be no additional cost for forms. In fact, some contractors consider that there is an actual saving in the cost as it is not



Detail of blocks used in building shown on opposite page.

Fireplace on south porch,
Mr. Albert Moyer's
Residence.

Surface Decoration with
Colored Clays.
Special Facing.

necessary to use the better grades of dressed lumber and less care need be taken in assembling the forms.

Cost of Facing Mixture

A suitable facing 1 inch in thickness, composed of a standard Portland cement mortar or concrete with ordinary sand or stone screenings and crushed stone, can be placed at a total cost for materials and labor from about 2 to 3½ cents per square foot. Where white cement and an expensive aggregate, such as crushed marble, is used the cost of this facing will be proportionally higher. To this cost must be added the cost of finishing the surface after the removal of the forms. This will depend upon the method adopted, the condition and age of the surface and on the character of the work.

Cost of Bush Hammering

A thoroughly hardened plain concrete surface can be finished by bush hammering by hand, at the rate of from 50 to 100 square feet per day. With common labor at $1.75 per day the cost would be from 1¾ to 3½ cents per square foot. Skilled labor will furnish about the same amount of work but it will be of a better quality and the cost will be increased by the difference in the cost of labor. With pneumatic hammers and labor at $2.00 per day a very good surface has been obtained on concrete bridges at a cost of about 3 cents per square foot.

Cost of Brushing

Low, plain concrete walls, such as foundations, where it is not necessary to use scaffolding, have been finished by brushing at a cost of 1½ to 2 cents per square foot with labor at $1.75 per day. The cost of brushing more elaborate surfaces, and where scaffolding has to be used, will vary from 2 to 4 cents per square foot.

Cost of Rubbing

Finishing green concrete surfaces by rubbing as described with bricks of carborundum, emery, or natural stone will cost from 1½ to 3 cents per square foot. On one large job where a careful record was kept of cost of removing the face forms and finishing the surfaces of concrete retaining walls was found to range from 1¾ to 3 cents per square foot of exposed surface. The wall varied in height from about 2 ft. up to about 18 ft. On the sections where it was necessary to use scaffolding the cost of finishing was greater than where the men removing forms and finishing the surfaces worked from the ground.

Cost of Sand Blasting

Sand blasting the surface of thoroughly hardened concrete will cost about the same as bush hammering with an automatic tool. Only a comparatively large amount of work will justify the cost of setting up and operating a sand blast or an automatic tool outfit.

Cost of Acid Wash

The appearance of surfaces finished by brushing, tooling, rubbing or sand blasting is greatly improved by washing them with a dilute solution of acid and clean water. This work can be done by common labor and the cost should be but a fraction of a cent per square foot.

That concrete surfaces can be so finished as to present a decidedly attractive appearance is demonstrated by the results obtained on the

limited number of structures and surfaces shown in this booklet. To produce the desired effect exposed concrete surfaces should be faced with a suitable facing mixture and finished by one of the methods described. The first cost of such work will practically be the total cost. There should be little or no additional expense for up-keep as a properly finished concrete surface can be considered as permanent, will not deteriorate or require renewing, and when soiled as all exterior surfaces eventually are may be cleaned at a small cost by washing with a dilute acid solution and clean water.

By brushing, tooling or sand blasting a concrete surface all traces of form markings are erased, the film of mortar that flushes to the surface next the forms is removed, thereby exposing the aggregate, and a rougher more artistic surface is produced. The roughness of the surface breaks up the light, the color of the exposed aggregate adds color and life, and a pleasing, artistic concrete surface is obtained.

Considering the marked improvement in the appearance of finished over form work, it is remarkable that so little attention has been given heretofore to the proper finishing of exposed concrete surfaces, and it is hoped that this booklet will serve as an incentive for increased activity in this respect.

Small Farm Buildings of Concrete

A BOOKLET OF PRACTICAL INFORMATION FOR THE FARMER AND RURAL CONTRACTOR

PREPARED BY THE
INFORMATION BUREAU
UNIVERSAL PORTLAND CEMENT CO.

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SECOND EDITION
1914

Small Farm Buildings of Concrete

PART I of this booklet is intended to furnish specific information on the construction of foundations, floors, walls and roofs of small concrete farm buildings, while Part II gives instructions and plans for putting up dairy buildings, ice houses, hog and poultry houses, root cellars and other similar structures of concrete. The construction of barns, corn cribs, granaries and silos has not been taken up in the present volume. "Concrete Silos," a 100-page booklet by the Information Bureau of this Company, will be sent free to those desiring reliable information on the subject of silo building. Persons seeking information on the subject of concrete barns, corn cribs, or granaries will receive, free of charge, assistance in the shape of suggested plans and general information on request to the Information Bureau.

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Small Farm Buildings of Concrete

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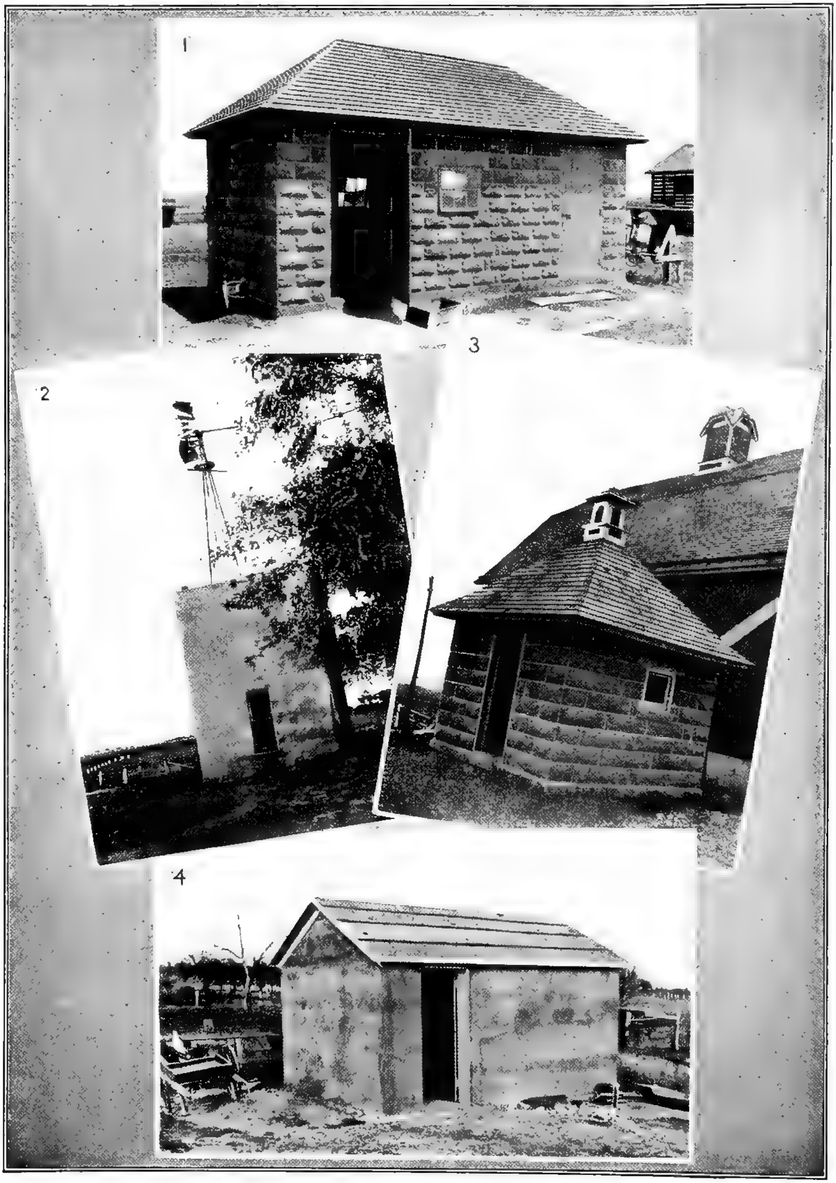


Figure 1. CONCRETE DAIRY BUILDINGS

(1) Concrete Block Dairy House.

(2) Monolithic Dairy Building with Water Supply Tank, built on the Farm of I. R. Little, Farmer City, Illinois. Dimensions, 12 feet square. Cost, $200.

(3) Milk House, Engine and Pumping Room on the Farm of John Arends, West Chicago, Ill. Dimensions, 10 feet x 20 feet.

(4) Monolithic Milk House on the Farm of Fred Mosedale, St. Charles, Illinois.

Small Farm Buildings of Concrete

PART I.

THE five log houses of Plymouth, built by the Pilgrim Fathers nearly three centuries ago, were probably the first substantial buildings constructed by the white man in America. With the advent of the white settlers the log cabin superseded the wigwam of the savages, and during the period when saw mills were scarce and timber plentiful to the point of being burdensome, the log building was the logical—indeed the only possible kind. The sawmill followed the settler and as sawed lumber became more plentiful the frame building logically superseded the log building.

Today lumber for many purposes has reached an almost prohibitive figure, and the rapidly diminishing supply gives no hope of future reductions in prices. Furthermore, in most sections of the United States the best lumber is already used up, and the quality of the future supply will not equal that of the past. Instead of having timber to destroy, as did the settlers of a generation back, the farmer of today finds good timber scarce, and lumber expensive.

Figure 2. Concrete Block Building on the Farm of Oliver Jensen, Early, Iowa, containing ice, dairy and store rooms. Dimensions, 16 feet by 22 feet. Cost, $225.

Concrete is taking the place of lumber, because, beside all of its other advantages it is cheap, and in every sense of the word economical of home labor and materials. Under a man competent to oversee the work, the most unskilled farm laborer can readily be trained to mix and place concrete properly, while men skilled in carpentry are required to do the work on frame buildings. Most farmers have gravel or sand on the place or can obtain it at small expense, and in many instances, the only material which has to be bought outright is the cement.

The last few decades have witnessed remarkable progress in the manner of raising animals for the market, in dairying and the growing of crops as well. A few years ago, hogs were protected during the winter only by rude shelters, and in the Northern States, were not marketed until the second year. Because of the lack of protection during cold weather the farrowing season was necessarily short, and the profits of

the hog raising business seriously curtailed. The situation was much the same in the raising of other animals. The introduction of substantial buildings—preferably of concrete—is changing conditions to a remarkable extent, simplifying and lightening labor and increasing profits.

The phenomenal growth of the dairy business in sections of the country adjacent to the great centers of population has brought with it a demand for better facilities for keeping milk and other dairy products clean and cool. To accomplish best results, the concrete milk house or dairy building, equipped with concrete floors and tanks, is necessary. Such a building is cool in summer and warm in winter, is proof against rats and mice, and easily kept clean. It contains no rotting wood construction to form breeding places for germs, and no crevices in which dirt can collect.

The Choice of a Building Material

Requirements of Good Farm Buildings. The most suitable building material is the one which meets the requirements of good farm buildings in the most satisfactory manner, that is, within the limits of allowable expense both for first cost and upkeep. One of the Cornell University bulletins, in discussing the requirements of good farm buildings, enumerates them as follows:

1. To keep animals and other objects dry.
2. To maintain a proper temperature.
3. To secure pure air, with a proper degree of humidity.
4. To secure light.
5. To secure cleanliness.
6. To prevent the breeding of vermin (rats, mice, insects.)

Figure 3. A Group of Concrete Buildings, Knollwood Farm, East Norwich, Long Island, New York.

7. To preserve the manure.
8. To secure health, comfort of the animals, freedom from injury, and to prevent the spread of contagious diseases.
9. To secure economy in feeding and watering.
10. To secure economy of space.
11. To secure economy of labor.
12. To secure economy of construction.
13. To secure strength and durability.
14. To secure good appearance.

In addition to the points mentioned in the Cornell Bulletin, the matter of protection against fire is certainly of greatest importance to the farmer and will be discussed at length under the heading "Fire Losses and the Insurance Problem." (Page 13.)

The first requisite is that the building keep out rain and dampness. Animals must be kept dry if they are to be kept warm, and keeping them comfortably warm means the saving of a considerable portion of their energy. Crops and all kinds of farm products, as well as implements and tools, building materials and other articles, cannot be stored in damp or wet places without injury. The second requisite, that of proper temperature is of importance where there are young animals to be taken care of, dairy products to be kept cool, or ice to be preserved.

Pure air is essential to all animal life, and absolutely necessary where dairy products are concerned. Unrestricted sunlight is the greatest enemy of bacterial life, and wherever animals are kept, an abundance of light practically insures freedom from disease. Cleanliness has been placed next to godliness. It is the one paramount requirement where articles of human food are concerned. There is no excuse for the dirty, wooden dairy, or the disease-laden and rat-infected buildings often used to shelter poultry and animals.

Figure 4. Farm Office Building of Reinforced Monolithic Construction. Morgan Farm, Beloit, Wisconsin. An office building is a great convenience on the modern large farm. Even the roof of this structure is of concrete.

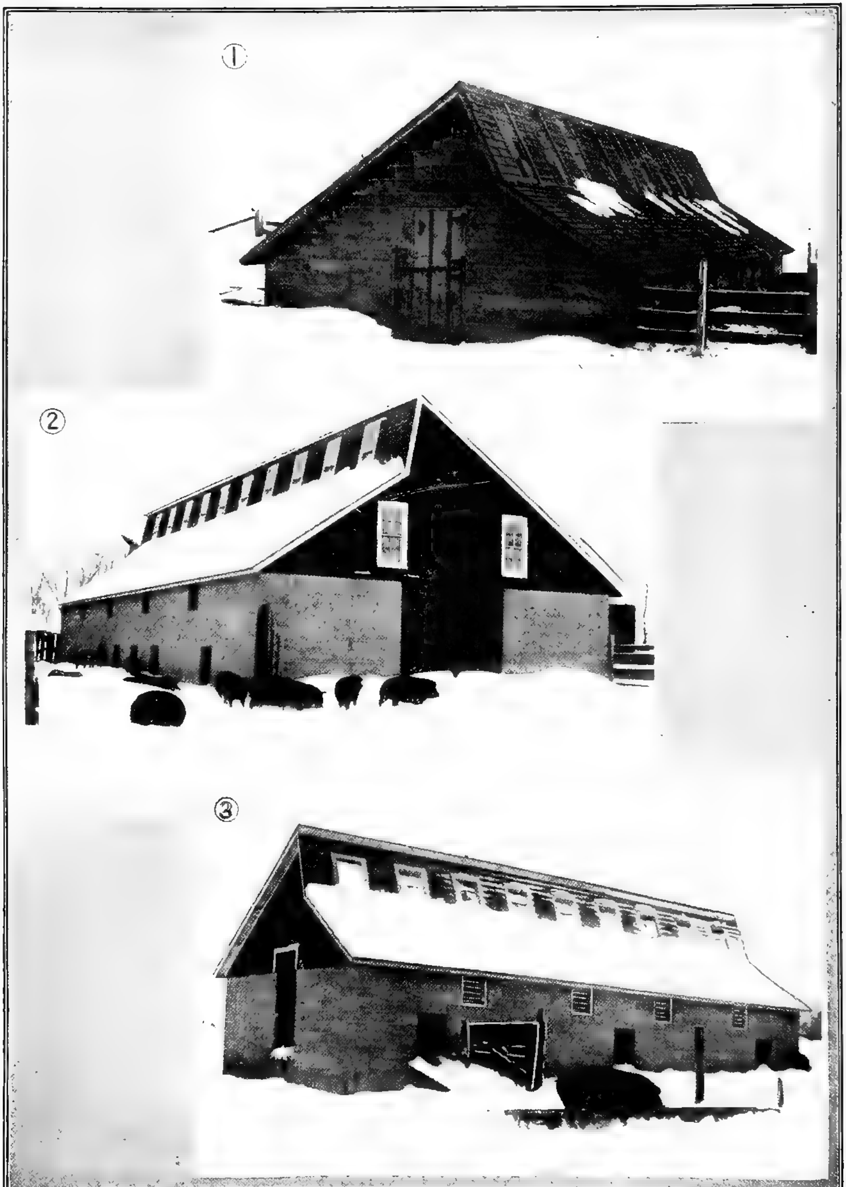


Figure 5. WINTER HOG HOUSE SCENES

(1) Hog House of N. Hampe, Rock Rapids, Iowa. Dimensions, 24 feet by 42 feet. Cost, $450. Built of Anchor block.

(2) Charles Klein's Hog House, Rock Rapids, Iowa. Dimensions, 20 feet by 40 feet. Cost, $450. Built of Anchor block.

(3) E. F. Hershey's Hog House, Early, Iowa. Dimensions, 20 feet by 40 feet. Cost, $350.

Economy in feeding and watering is of great importance and includes not only the saving of feed and water, but also the saving of the labor of feeding, as well. Economy of space often involves a saving in the expense of the building and in the convenience of using it. Economy of labor means the lifting of irksome farm burdens, and consequently the shortening of working hours and a larger amount of time for educational and recreative pursuits. While economy of construction is desirable in that it keeps down the first cost of a building, strength and durability are desirable in that they insure permanence and low expense for upkeep. Good appearance is by no means a minor consideration, especially where it can be obtained without additional expense. The day oi beautiful landscapes defiled by unsightly structures should be past. Beautiful buildings give the farm an air of home which cannot be obtained by any other means.

How Concrete Meets Requirements. No material meets all of the requirements mentioned in the preceding paragraphs so well as does concrete. Good concrete is water-tight, and a good concrete farm building with a concrete roof is dry, clean, durable and can be made pleasing in appearance, without additional expense. The concrete floor makes the feeding of animals or poultry easy and economical, and the concrete walls leave no place for rodents or vermin. The walls are light in color, reflecting light into all parts. Concrete construction leaves no small corners, crevices, or pockets for dirt to collect.

Figure 6. Monolithic Pump House, Jelke Dairy Farm, Dundee, Illinois. One of several concrete structures on the Jelke Farm.

Logical Design of Farm Buildings. Perhaps one of the greatest hindrances to progress in the design of farm buildings at the present time is the tendency toward blindly following the design of other buildings in the neighborhood, perpetuating faults and continuing incorrect practice, often with much waste. The crying need at the present time is for logical design. Each building should carefully be planned for the service required of it, considering local conditions but discarding local peculiarities of design, which are often false guides. Additional effort expended to make plans meet, in the best possible manner, the

particular needs in each individual case, is always repaid in the long run in convenience and lower cost of maintenance.

In designing structures to be built of concrete it is often economical to depart from the approved designs for frame structures. This is particularly true in the design of the roof. Concrete roofs may be built quite flat, a pitch of $\frac{1}{4}$-inch to the foot being sufficient to run the water off. The windows of buildings with solid concrete or cement plaster walls may be put in without sills and lintels. Chimneys and flues may be built up within single or double monolithic or concrete block walls.

Economizing Home Materials and Spare Time. It very frequently happens that a farmer or rural contractor has available at small expense, all of the ingredients of good concrete excepting the cement. In such cases, concrete is certainly the logical material to use in all construction work, because it economizes to the greatest possible degree home resources, employing valuable materials which cannot be used to so great an advantage in any other way.

One of the big problems of farm management is the planning and arranging of work so as to keep the help busy at all times. In spite of the most careful planning, and the most systematic methods of doing farm work, uncertainties of weather and other conditions beyond control make it practically impossible to avoid a considerable loss of time. Such periods may often be used conveniently for doing jobs of concreting. If the weather is too disagreeable for outside work, the time may be spent in preparing the form lumber and arranging details of the work, or in making concrete blocks, sills, posts, slabs or other work indoors.

Figure 7. Stallion Barn on Col. G. Watson French's Iowana Farm near Davenport, Iowa. A structure with pleasing lines and convenient interior arrangement.

Fire Losses and the Insurance Problem

Fire Losses. The great majority of farm building losses are from a single source—fire. The loss on American farms, due to this terrible agency, is almost inestimable, as insurance statistics covering the value of farm buildings destroyed do not include the enormous additional losses in time, inconvenience and property, which follow conflagrations as direct or indirect results. Insurance experts declare that an average of 500 buildings are destroyed by fire every day in the United States alone, making an average of one building every three minutes, day and night. The money value of this enormous waste has been placed at $250,000,000, annually, and an additional $150,000,000 is spent every year for the maintenance of fire departments, high water pressure systems, and other means of protection against fire. A very small percentage of this latter sum is used, however, in the protection of farm property.

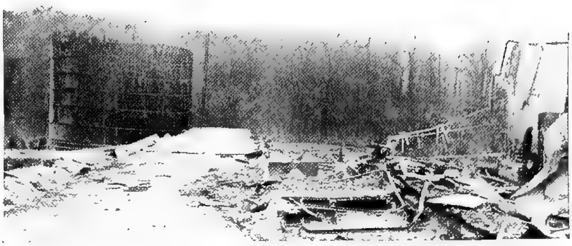


Figure 8. Ruins of Dairy Barn and Silo, Crabtree Dairy Farm, Lake Bluff, Illinois, after a fire, November 3, 1910.

Ordinary frame farm buildings, far removed from fire protection of any kind, generally meet total destruction when attacked by the flames. This fact has been generally recognized, and as a result, there has been a big demand for fire insurance, which might be more properly known as fire indemnity. The comparatively high insurance rate which farmers are now paying, is based upon the experience that the salvage from fire-swept frame farm buildings is generally small.

Fire Insurance and Fire Protection. It is obvious that fire insurance and fire protection are two entirely different things. The first merely pays the value of the property lost by flames, the other prevents the flames. Fire insurance pays the owner what the burnt portion of his building was worth, but very rarely the sum total of what the fire cost him. It cannot repay the owner for the inconvenience which he and his family may suffer, neither will it reimburse him for the loss of precious time during a busy season, the possible loss or enforced sale of stock, the interruption of business, nor the loss of articles of value as keepsakes. Real fire protection is only possible through fire prevention. It does all that fire insurance cannot do—by preventing the injury, rather than by attempting to make amends after it has occurred.

Preventing Fire Losses. Where fires cannot be prevented, fire insurance is desirable; but given an opportunity to choose between *fire insur-*

ance and *fire prevention*, the arguments are obviously in favor of the latter. It is equally obvious that the only time to prevent fire is before it appears and it is apparent that the logical method of preventing fire is by building of fireproof construction. Fire fighting apparatus is only effective if used at the critical moment—when the fire starts. The chances of reaching a fire at the critical moment, however, are small. On the other hand, the fireproof building is constantly protected, even though the owner be away from home.

Concrete farm construction is fireproof. In the days when concrete buildings were more expensive, the excuse for not building them was because of their cost. Today, no such argument is possible, for the cost of concrete farm buildings does not greatly exceed the cost of wood in any locality, and in many places it is as cheap as wood; when freedom from insurance premiums and future repair bills is considered, concrete is actually cheaper than wood. These statements are particularly true when home labor and materials are available.

If the buildings are of fireproof concrete construction they may be placed more closely together thus saving much unnecessary labor. Aside from the consideration of cost, it is probable that no farmer ever doubted the advisability of putting up his buildings of fireproof concrete construction.

Figure 9. Small Gasoline Storage Building, Rochester, Wisconsin, built of concrete block and concrete brick. A very desirable type of building for the farmer with an automobile.

Foundations

Laying Out the Work. Buildings are usually located with reference to some existing object, such as a highway, a drive, or some other buildings. Where the location of the building depends upon some other object, the first line to be determined should be the one influenced by the location of that object. With this established, it may be used as a base line, and the corners which come on it should be located next. In case the building is not located with reference to some other object, the base line should be chosen arbitrarily, and the corners and other lines laid out from it.

One corner will probably be located with reference to some other object, and the other corner on the base line will be located a distance from the first equal to the length or breadth of the building. Mark these by stakes driven in the ground, the exact points being indicated by a nail driven in the stake. These corners are referred to in Figure 10 as "A" and "B," A B being the base line.

After the corners on the base line are definitely located, proceed to locate another corner, marked "C" in Figure 10. The line which runs from "A" to "C", perpendicular to the base line, must first be located. To secure a true right angle at "A" measure accurately 6 feet from "A" along the base line toward "B", and mark this point carefully by a stake and nail, as indicated by "Y". Now measure out exactly 8 feet from "A" in the direction of the corner to be found, and mark a curved line on the ground; measure from "Y" 10 feet to a point on the curved line; drive a stake at this point and then check the measurement, and mark the location accurately with a nail in the stake. This point is marked "Z" in Figure 10. The point "C" will lie on the line "AZ" projected. Corner "D" can be located from "B" the same as "C" was located from "A."

Should the proposed structure be irregular in outline, it will be necessary to project the base line far enough to locate all corners from it. In

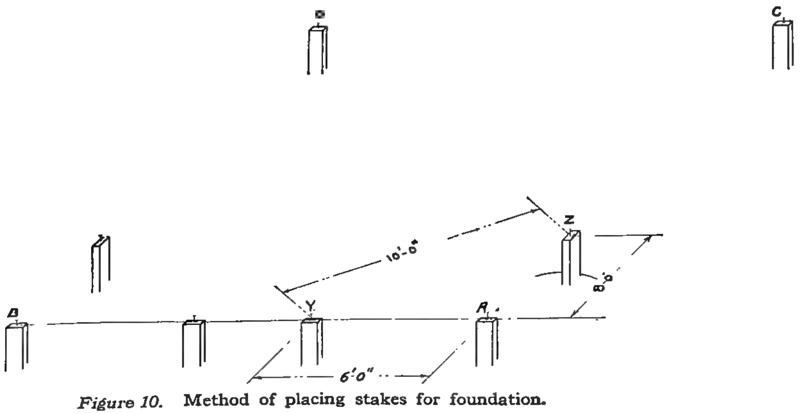


Figure 10. Method of placing stakes for foundation.

such a case three or more points may be located on this line, but the location of the other corners will be accomplished as described.

Locating Construction Lines. After having the corners located it is necessary to establish these points in a way that they will remain permanent during the construction of the foundation, and this is best accomplished by building at the corners, fence-like forms. (Fig. 11). These should be constructed back at least 8 feet from the foundation lines and should be long enough to permit of marking both the inside and outside foundation lines on the horizontal or top boards. Brace the frames sufficiently to withstand the pressure of the tightly drawn cords, which they must support as nearly horizontal as possible.

The points on the corner boards will be located by drawing a cord from one board to the other, bringing it directly over the nails at the two corners on the same line; these points should be marked accurately on the board by a notch, or by cutting a shallow groove with a saw. This cord represents the outside line of the foundation; the inside line will be indicated by measuring in a distance equal to the thickness of the proposed foundation and stretching a cord between these two points. Carefully mark these points on the board in some way different from the marks showing the outside line.

Excavations. With the lines properly located and marked at all corners the excavating may be started. It is usually recommended that a foundation be put down below the point reached by frost, but unless the natural drainage of the soil is poor it will be unnecessary to excavate to a depth of more than three feet, provided solid earth is found at that depth. A foundation must be established on solid ground, all loose earth or loam being removed. Also if "made ground" or a fill be encountered this must be removed to whatever depth is necessary to secure solid earth. Excavating for a foundation until a suitable earth footing is secured may result in an uneven bottom in the foundation trench. Such a condition might prove somewhat annoying if the foundation was to

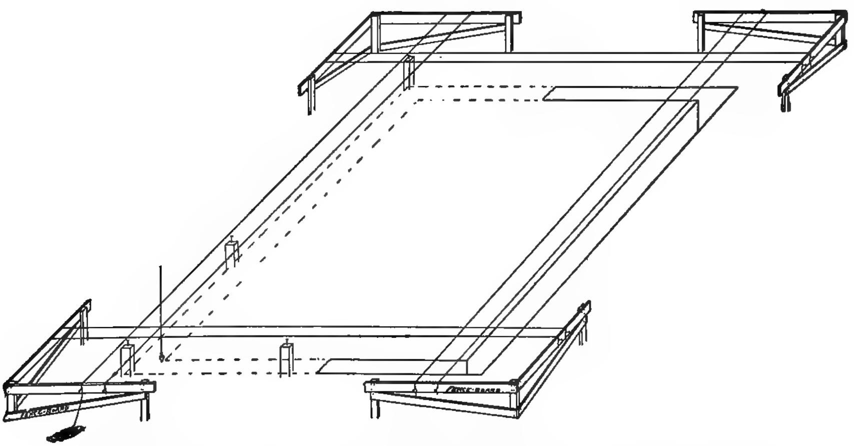


Figure 11. Stakes and Construction Lines indicating location of foundation walls.

be of stone or brick but with concrete the construction will progress the same on an uneven as on an even bottom.

In preparing for a foundation in soil which will stand in a vertical position and when provision for a basement is not necessary, an excavation may be made into which it is possible to place the concrete without the use of forms. When this is practicable, the width of the trench should, as nearly as possible, be the same as that desired for the breadth of the foundation.

When the concrete is to be placed directly into an excavation, care should be taken to protect the edges and to keep dirt out of the concrete. This can be accomplished by placing two or more short pieces of 2-inch lumber across the trench and upon these 2 x 12-inch plank, so placed that they project over the edges of the trench about an inch.

A strip of burlap, building paper, or some similar material should be tacked along the edge of the board on the bank of the excavation opposite that from which the concrete is to be deposited. This covering should hang into the trench far enough to protect the walls at a point where the concrete strikes when dumped from the wheelbarrow.

Forms for Foundations Below Ground. Sometimes because of the nature of the soil, or possibly because a team and scraper are used in removing the earth, the walls of the excavation cannot be kept perpendicular. In such cases forms must be provided for that portion of the foundation below ground, as well as for the portion above ground if there be any.

Unless forms for the whole foundation are to be put up at one time it will be best to build them flat on the ground, in units of convenient length, and then erect them in place. By having the forms constructed in this way they may be removed and used again, with the minimum

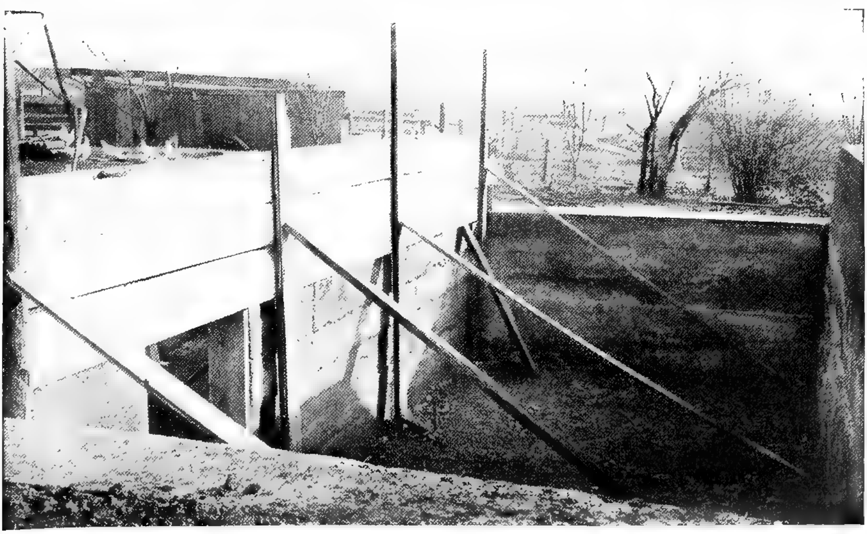


Figure 12. Concrete Foundation for a Farm Building, showing method of bracing forms.

damage to the lumber. In building forms flat, the stringers should be carefully leveled and the uprights and sheeting carefully placed in the correct relative position, otherwise the form will be askew when erected.

If the forms are to be built in position, first place the stringer shown at the bottom of the inner form, Fig. 13, so that when the upright 2-by-4's and the sheeting are in place, the inside face of the sheeting will be in line with the inner face of the proposed wall. Nail the lower end of the uprights to the stringer and attach the top board of sheeting to hold the vertical 2-by-4's at the proper distance apart. This frame must now be plumbed carefully and held in place by the braces extending between the upper end of the 2-by-4's and stakes driven into the ground. The remaining sheeting boards may then be placed, starting at the bottom. With so much of the inner form set, the outer one can easily be placed and fastened to the inner one, as shown in the sketch. On account of the small space in which to work, the outer part of the form can more easily be built in sections as described, and lowered into position. When the forms are not to be handled in sections, it will be advisable to "break joints" in placing the sheeting, for by so doing, the form will be somewhat stiffer and the alignment will more easily be maintained. In erecting forms one must bear in mind that they are to be removed and when there is only a narrow space between the forms and the earth wall, provision should be made for their removal by a means which will result in the least damage to the lumber.

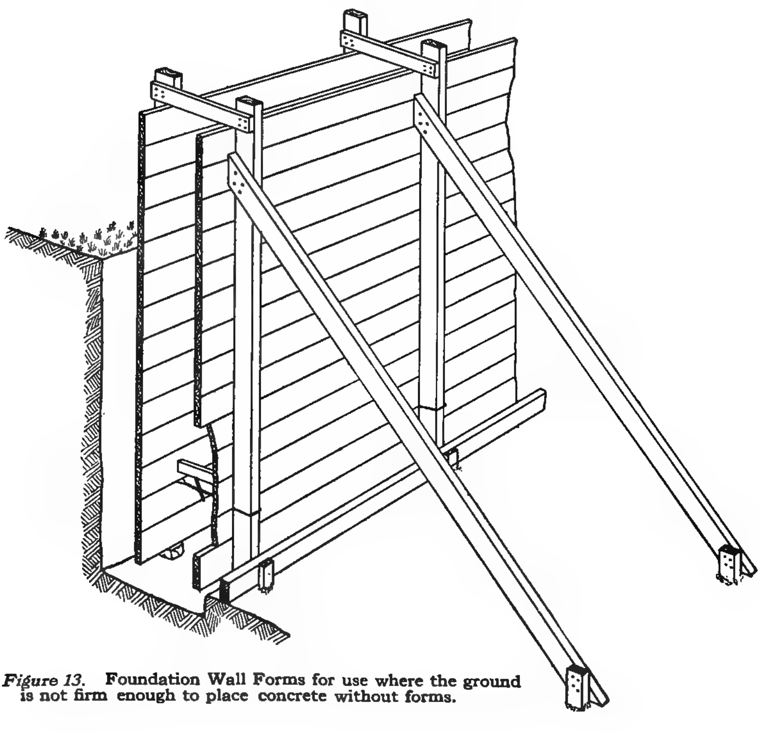


Figure 13. Foundation Wall Forms for use where the ground is not firm enough to place concrete without forms.

It will be noted in the sketch (Figure 13), that the outer form is allowed to rest on stones, so that the lower sheeting board is raised a short distance from the floor of the footing excavation. This allows the concrete to spread out at the bottom of the wall, providing a wider base, which is sometimes desirable.

Instead of supporting the outer part of the form by independent bracing into the earth, it will be better to wire it to the inside section. Spacing blocks of a length equal to the thickness of the wall, should be inserted to keep the two sections of the form in the correct relative position. The wires are then twisted with a piece of iron or a large nail, until the outer section is drawn against the spacing blocks. The top of the uprights are fastened together with cleats (K), as shown in the sketch. If the wall is high it may be necessary to put in additional wires and blocks near the center of the uprights.

Some means must be provided for removing the spacing blocks as the concreting progresses. This can be done by attaching a wire to the block by which it can be withdrawn after being knocked loose.

Figure 14 shows a type of form to be used when a wide base is wanted. This provides for a batter on the outside face of the foundation. The details of construction are the same as given for Figure 13 with the exception that the bottom sheeting board on the outer form is allowed to rest on the floor of the excavation. In case it is desirable to make that part of the wall extending above the ground level plumb, small wedge-

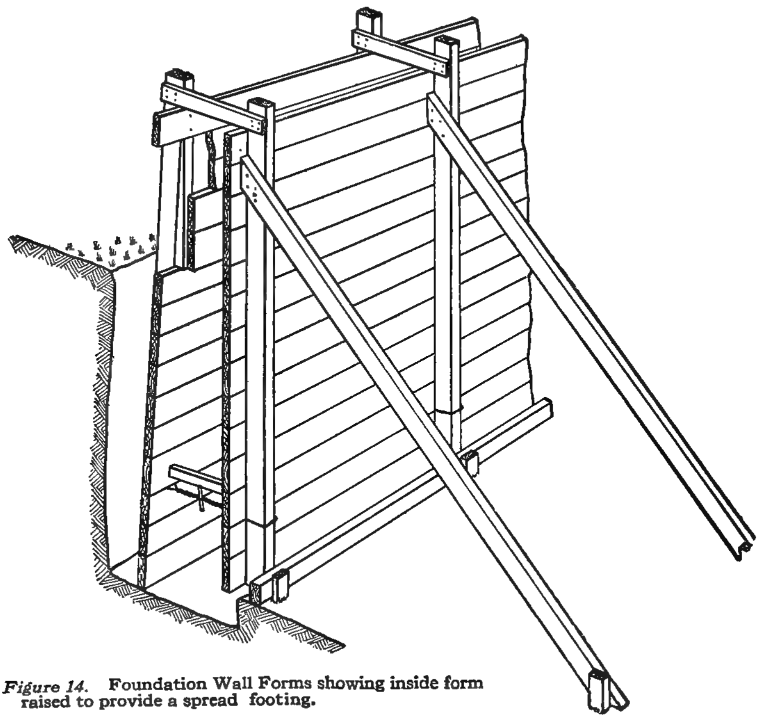


Figure 14. Foundation Wall Forms showing inside form raised to provide a spread footing.

shaped blocks can be attached to the 2-by-4 uprights of the outer form, and the sheeting nailed to these blocks.

In Figure 15 is shown a type of form used when the character of the soil will permit of placing concrete directly against the earth, doing away with that part of the outer form below the ground level. The inner form is erected as described in Figure 13 and the concrete placed up to within a few inches of the ground level. When depositing concrete in this type of form, care must be exercised, as dirt is likely to be knocked off the sides of the bank into the concrete. The edge of the excavation should be protected with boards, as previously described. The small outer form is built in sections and set up as shown in Figure 15 and the concrete for the remainder of the wall placed in the usual manner.

It will be noted that all forms can be built with stock length lumber, requiring very little sawing, which permits of the lumber being used later for other purposes. If a smooth face is wanted, dressed lumber should be used.

Foundations Above Ground. Foundations for monolithic and concrete block structures need not be carried up above the ground line, as is customary with cement plaster, frame and brick buildings erected on a concrete base. Where the walls are to be continued up of monolithic concrete or concrete block, the top of the foundation should be leveled off, so that the forms for the walls may conveniently be placed thereon. The top of the foundation should not be trowelled, as trowelling makes

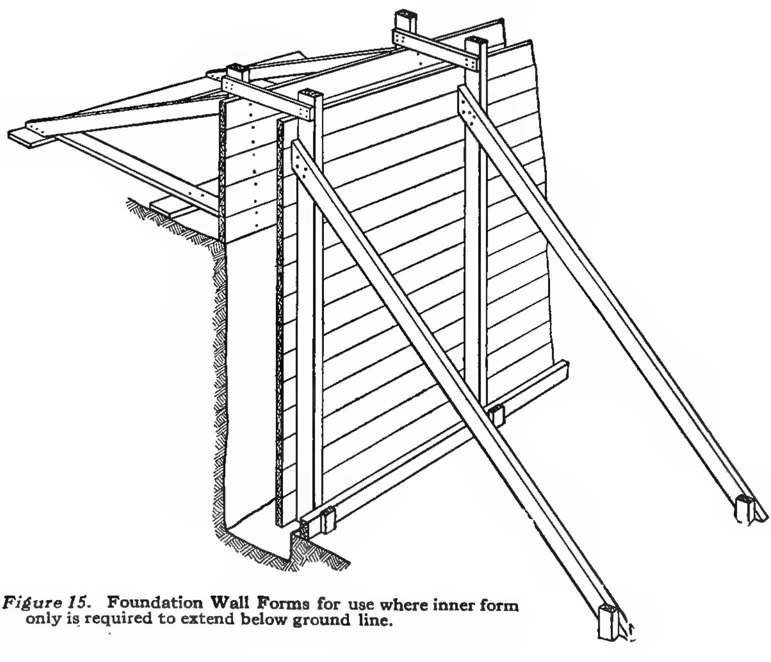


Figure 15. Foundation Wall Forms for use where inner form only is required to extend below ground line.

it more difficult to secure a good bond between the foundation and the wall proper, when the latter is to be continued up.

It is quite desirable, of course, that the floor of all buildings be somewhat higher than the surrounding ground level, and to make this possible it is customary to carry the foundation of buildings other than monolithic and concrete block, a short distance above ground. For this purpose, forms are required. Suitable types of forms for projecting the foundation walls above ground are shown in Figure 16.

The forms shown in Figure 16 can either be constructed in sections and then set into position, or built in place, depending somewhat on local conditions. If the inner and outer parts of the form are built separately, in sections, they may be leveled carefully and plumbed as units, while if built in position, care must be taken in placing each timber. In all cases the bottom boards of the sheeting should be flush with, or a little below the top edge of the trench. The top boards of the sheeting should be the height of the finished wall.

From the figure it will be noted that the forms are suspended over the trench and not allowed to rest on the new concrete. This is accomplished by placing stringers on the ground a short distance back from the trench, supporting the triangular frame bracing.

If the building is of large dimensions, considerable lumber will be required to provide forms so that the whole job can be executed at one time, therefore it will be found cheaper to build the forms in sections the stock length of the sheeting boards. Four to six sections will be ample, unless a large force is employed. The forms can be removed and used again when the concrete has hardened sufficiently. By planning the work in this way a small amount of lumber will make all the forms necessary for the foundation of a large building.

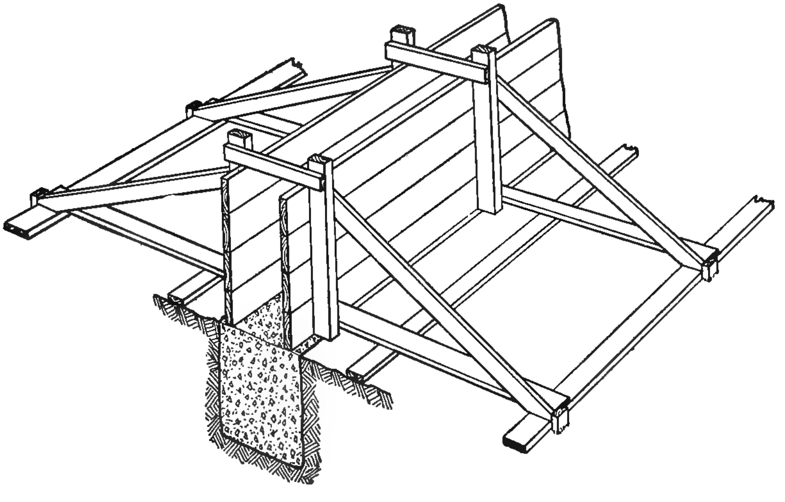


Figure 16. Form for Foundation Wall above ground.

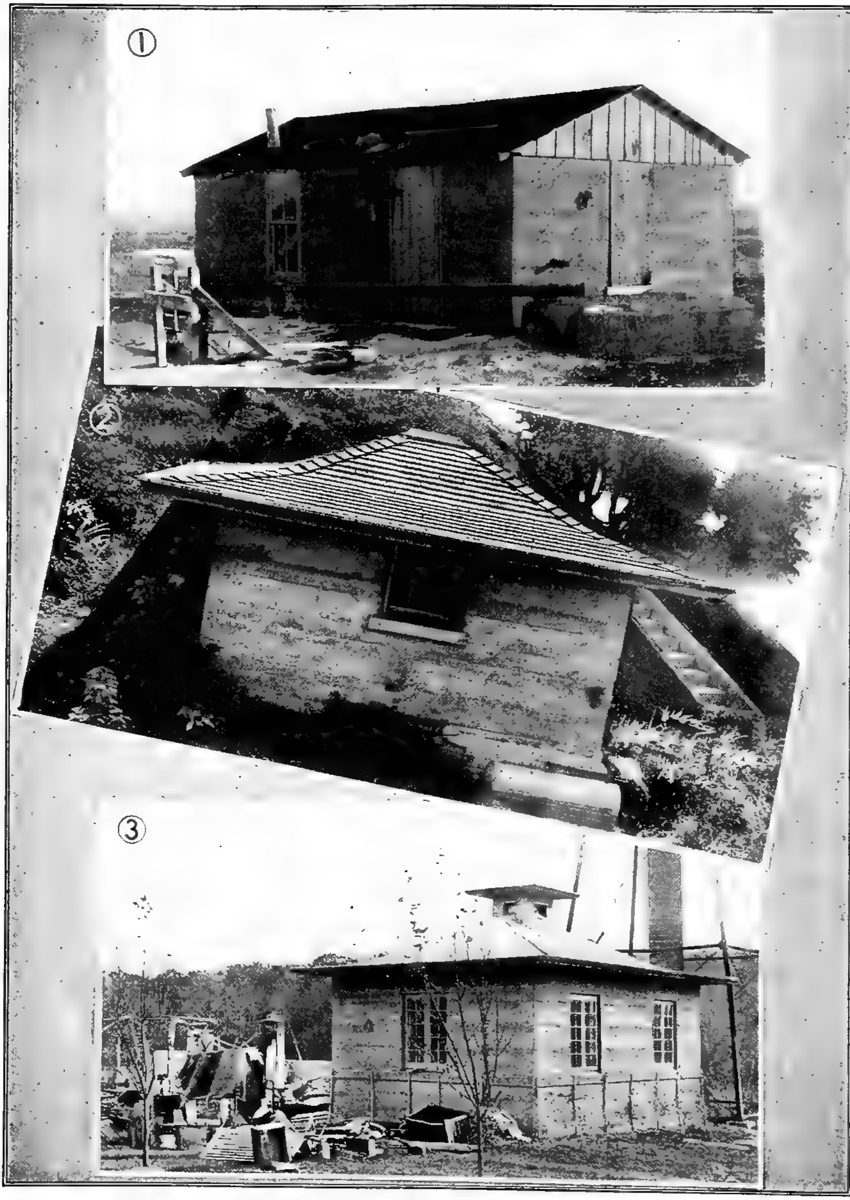


Figure 17. CONCRETE PUMP HOUSES

(1) On George Lee Tenney's Ranch, Grover, Colorado. Dimensions, 14 feet by 26 feet. Built by the owner at an expense of $32.55.

(2) On the Morgan Farm, Beloit, Wisconsin.

(3) On the Crab Tree Dairy Farm, Lake Bluff, Illinois. The only building left standing after a recent fire.

Concrete Floors

ONE of the most important parts of any concrete farm building is the floor, and there are many reasons why it should be of concrete. The principal considerations are those of convenience, sanitation and cost and on all three of these points a concrete floor has practically no rivals. There is no excuse today for the rotting, germ infected wooden floors formerly so common to farm buildings, with their uneven surfaces and occasional broken boards and rat holes. Wooden floors are seldom properly drained, owing to the fact that it is impracticable to make and keep them tight. Drainage is easily provided with a concrete floor, assuring good sanitation.

The first thing to consider in the building of a floor is the character of the soil to be covered. Sometimes when the soil is heavy and holds water, a sub-base or foundation of gravel or cinders is advisable, but when the soil has good natural drainage, the sub-base is not necessary. If a sub-base is desired, excavate the area to be covered by the floor to a sufficient depth to permit placing 8 inches of gravel or cinders beneath the floor. The gravel or cinders should be packed well by thoroughly wetting and tamping. Forms will not generally be required for the floors of small buildings, but in cases where necessary, they should be made of lumber 2 inches thick. One-inch material requires more stakes and cannot be kept in as good alignment as heavier stuff. Floors of farm buildings are generally made 4 inches to 6 inches thick, for which 2 by 4-inch or 2 by 6-inch form lumber should be used. If the floor is to look well when completed, care must be taken to place and keep the forms straight and even and they should also be leveled carefully.

Drainage. For the purpose of securing good drainage the floor should be made to slope toward some suitable point; a quarter inch to the foot is ample slope for this purpose. In small milk houses the floor may be sloped toward the tank, and the water conveyed to an outlet

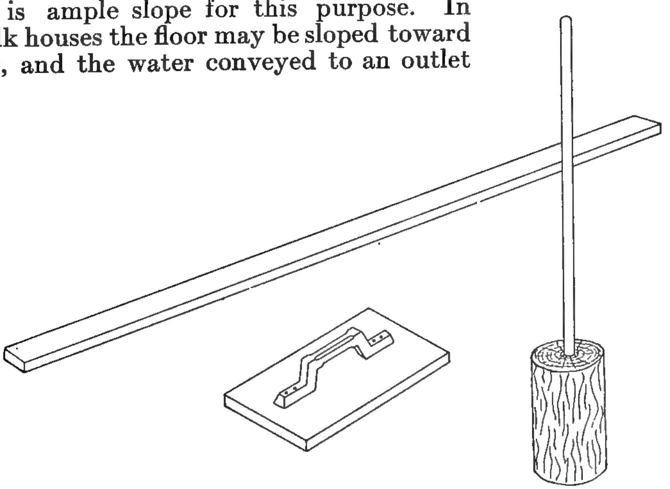


Figure 18. **Straightedge, Wooden Finishing Trowel and Wooden Tamper. Home made tools required for laying floors.**

by a small gutter running along the floor close to the tank, as shown in Figure 65 on page 78; ice house floors should drain to a central outlet, piped so as to prevent warm air from entering the ice chamber (see Figure 65, page 78); floors of poultry houses and similar structures may drain to the outside or to a center drain as desired, while the hog house floors should be provided with gutters at the sides of the feeding alley. Before beginning the actual construction of the floor, the manner of draining must be decided upon, and plans laid accordingly.

Single Course Work. Single course floors for farm buildings should be 5 to 6 inches thick, with concrete mixed in the proportions of 1 sack of cement to 2 cubic feet of coarse, clean sand, and 3 cubic feet of screened gravel or crushed stone. Enough water should be used so that the concrete is "quaky" and will need but little tamping.

For floors of hog and poultry houses, sheep sheds, ice houses, etc., one course work is recommended. In this case the entire slab is placed at one time and the top finished off with a wooden trowel. A mortar coat as used for sidewalks is not put on, but a small amount of mortar may be spread over the surface if necessary, to trowel the surface smooth. It is good practice, however, to brush the concrete with a broom, before it is hard, so as to give a better footing for persons and animals.

Two Course Work. For the body of two course floors, a mixture in the proportion of 1 sack of cement to 3 cubic feet of clean, coarse sand and 5 cubic feet of screened gravel or crushed stone will be found suitable. Sufficient water should be used in the concrete to produce a mixture which when placed will show moisture readily on the surface. After the concrete is mixed, the quicker it is tamped into place the better. It must be placed before showing the least tendency to harden, and under no circumstances should the concrete be allowed to stand longer than half an hour.

The Surface Coat. In such buildings as dairy houses it is generally desirable to give the floor a mortar top ¾-inch to one inch thick. This

Figure 19. An excellent type of ventilated Concrete Block Corn Crib. Charles Griesemer, Hopedale, Illinois.

should be laid directly upon the tamped base while the latter is still wet and before it has hardened. Great care must be exercised in preventing sand, dust, clay or other foreign matter from getting into the base while it is exposed, for such material invariably prevents a good bond between the top and the base. The mortar for the top should be mixed in the proportion of 1 sack of cement to 2 cu. ft. of sand, sufficient water being used to make the mass spread easily. The mortar should be mixed in small quantities and placed as quickly as possible.

Mortar must never be used in the surface coat after it has started to harden. The spreading of the top should be done with a trowel and a straight edge, the latter being required in working the surface to a true grade. The top should be distributed over the base and worked to a uniform surface with as little trowelling as possible. A convenient straight edge is shown in Figure 18. It should be made of a piece of dressed lumber $\frac{7}{8}$-inch thick by 4 inches wide, and long enough to extend between forms. By careful use of the straightedge during the process of spreading and trowelling no difficulty should be experienced in obtaining a true surface, free from dips and hollows.

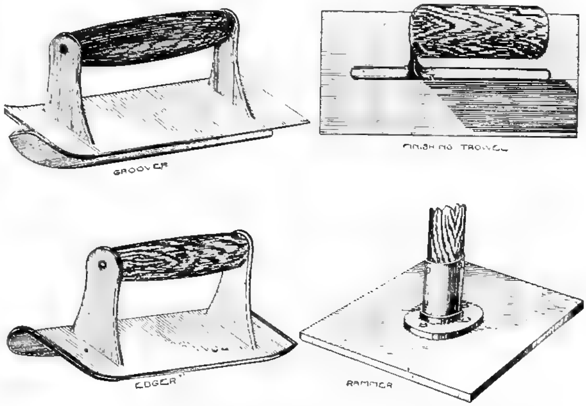


Figure 20. Steel Rammer, Finishing Trowel, Groover and Edger for finishing floors and sidewalks.

After the top is spread evenly, it is sometimes necessary to wait a little while before finishing it, but the top must not be allowed to stand too long, for after standing it may require excessive trowelling to get the finish desired. Excessive trowelling frequently causes checking which disfigures the work and also produces a surface which is smooth and slippery. Smoothing with a wooden trowel will leave the floor in much better shape than with a steel trowel. When the surface of the floor has been properly graded and has received sufficient trowelling, it should be marked off into blocks, not larger than 5 feet in either dimension. These marks should first be made with the point of a trowel and then worked down with a groover, which with an edge runner are the only finishing tools necessary that cannot be home made. (See Figures 18 and 20.)

After the walk or floor is finished it should be protected until it is thoroughly hardened. It should not only be protected against traffic, but against rain, frost or too rapid drying out. An excellent practice for out-door work is to cover with fine earth or sand as soon as the work will permit of such covering without being disfigured.

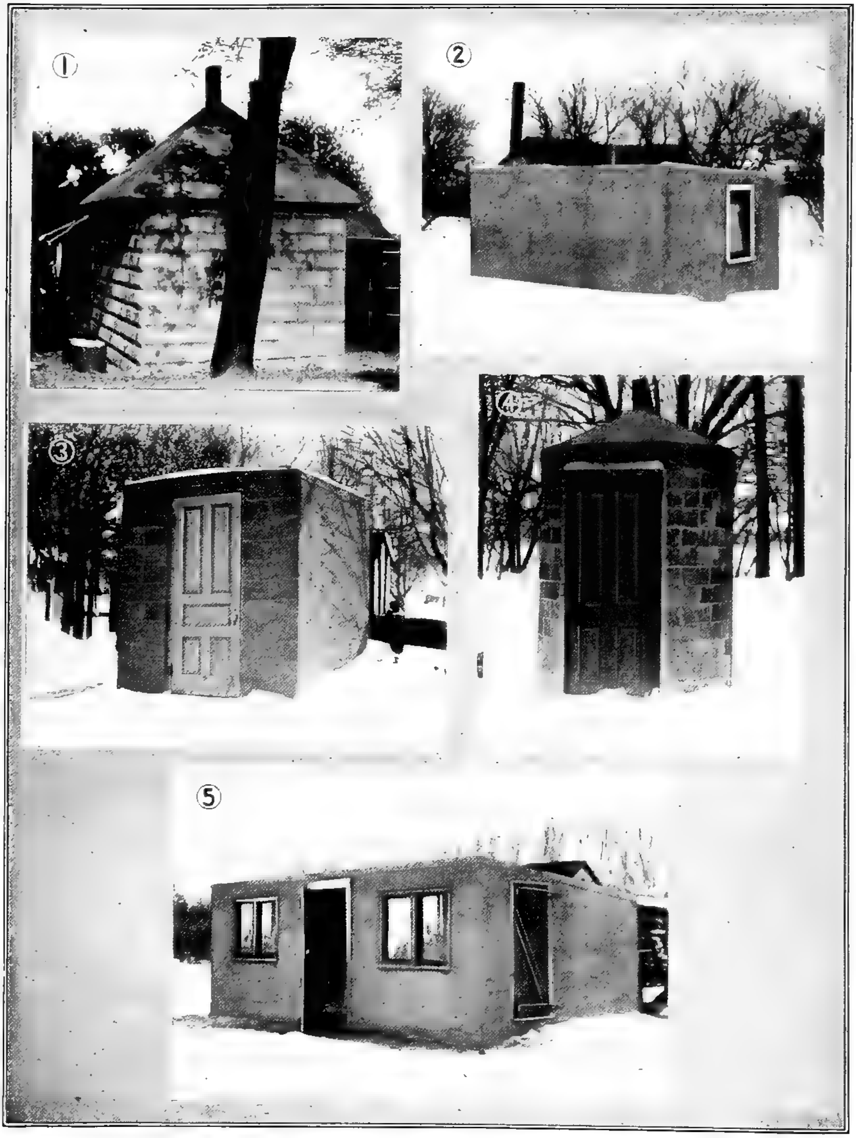


Figure 21. SMALL CONCRETE BUILDINGS ERECTED BY OWNERS

(1) Smoke House of Sam. Meyer, Bloomingdale, Illinois. Dimensions, 12 feet square.

(2) Bath House of W. S. A. Smith, Sioux City, Iowa. Dimensions, 10 feet by 10 feet.

(3) Smoke House of John Schram, Early, Iowa. Dimensions, 8 feet by 8 feet.

(4) Circular Smoke House of George Rosenhauer, Early, Iowa.

(5) Poultry House of W. S. A. Smith, Sioux City, Iowa.

Stairways and Steps

IF the building is to have a basement, or if it is to be more than one-story in height, concrete steps, or stairways should be provided. This work can be accomplished easily, and with the minimum amount of form lumber, by following the procedure laid down in the following paragraphs.

Basement Steps. The first step is to excavate the required space, after which the forms should be erected for the side or retaining walls. Simple forms, as shown in Figure 22 will answer. There is an advantage of building these forms in place, and bracing them rigidly, one against the other at the top and bottom; a smaller amount of lumber will be required, however, if one form is used first on one side and then on the other, bracing against the opposite wall. After the first side wall has become sufficiently strong, the forms are removed, the cleats are reversed, and the forms reset on the opposite side.

When in position, the forms for the side walls will rest upon the floor of the excavation made for the steps. As the walls will project above the ground at the building line and slope from this point to the opposite end of the entrance, an outside, rectangular form will be required for this portion, and should be constructed and established the same

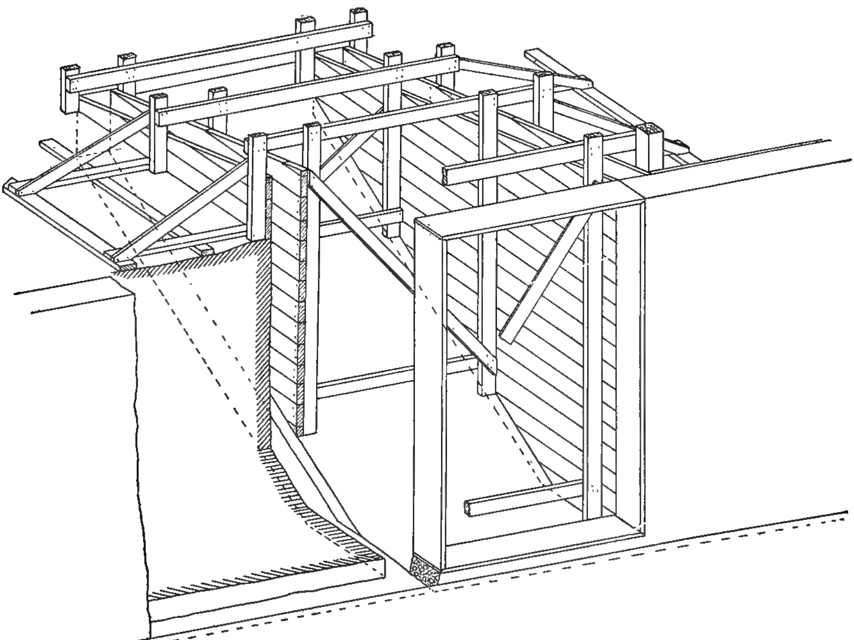


Figure 22. **Forms in position for retaining walls for cellar steps.**

as the form shown in Figure 16. The top of the inside form is attached to the outside form, and, in a small way, will help to support it. It will be noted that the sheeting boards are placed horizontally, for by so placing them, less cutting is required and, therefore, less waste of lumber.

If the forms for the side walls are put up so that both can be filled at the same operation, each should be braced rigidly at the bottom against the side of the excavation while being filled. After the concrete is in place on one side, the braces within the forms on the opposite side must be removed only as the concrete is placed, for by the pressure of the green concrete on one side, both forms will be pushed out of line unless sufficient bracing is maintained until the pressure is equalized by the concrete in both forms.

Step Forms. The best type of form is shown in Figure 23. Cross pieces are wedged between the side walls and assisted by a bracing, supported from a frame, also wedged between the walls. For a starting point mark on the side wall the position of the top of the finished landing, which should be the same elevation as the basement floor, (Figure 24). Measure out along this line from the face of the building wall a distance equal to the width of the proposed landing, less the thickness of the material to be used as cross forms; this point will be designated as "Q." From "Q" measure vertically a distance equal to the rise of one step; this point which will be referred to as "R" indicates the point to which the upper outside corner of the cross form will come.

Locate a point at the junction of the face of the side wall with the building wall, a distance from the level of the finished landing equal to the rise of four or more steps; measure

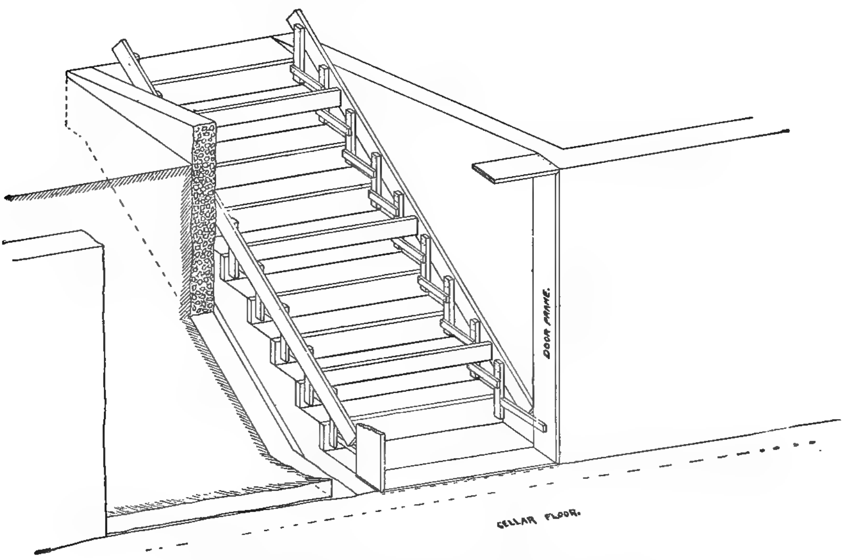


Figure 23. Method of laying out forms for cellar steps.

out from this point in a horizontal direction a distance equal to the tread of one less number of steps than used in getting the elevation, plus the width of landing, less the thickness of the riser form; this point will be known as "W." Draw a line along the face of the wall through "R" and "W." Starting at "R" the distance "X" between points can be selected from Table "A." After these points are located, project a vertical line through each by the use of a plumb level.

Table A

Distance "X." (See Figure 24)

Rise in Inches	TREAD IN INCHES							
	8½	9	9½	10	10½	11	11½	12
6	10⅜	$10\frac{13}{16}$	11¼	$11\frac{11}{16}$	12⅛	12½	$12\frac{15}{16}$	$13\frac{7}{16}$
6½	10¾	11⅛	11½	$11\frac{15}{16}$	$12\frac{7}{16}$	$12\frac{13}{16}$	$13\frac{3}{16}$	$13\frac{11}{16}$
7	11	$11\frac{7}{16}$	$11\frac{13}{16}$	$12\frac{3}{16}$	$12\frac{11}{16}$	13	$13\frac{7}{16}$	$13\frac{15}{16}$
7½	$11\frac{5}{16}$	$11\frac{11}{16}$	12⅛	12½	13	$13\frac{5}{16}$	$13\frac{11}{16}$	$14\frac{3}{16}$
8	$11\frac{11}{16}$	12	12⅜	$12\frac{13}{16}$	$13\frac{5}{16}$	13⅝	14	$14\frac{7}{16}$

The cross pieces which are held in place by wedges, should be cut about a quarter of an inch shorter than the distance between the walls. In placing these bring the face flush with the vertical line, the upper outside corner coming to the point located on the line "R."—"W."

In addition to wedging, which should be sufficient to keep the cross pieces in a true horizontal position, bracing, as shown in Figure 23 is desirable to keep them from being pushed out when the concrete is

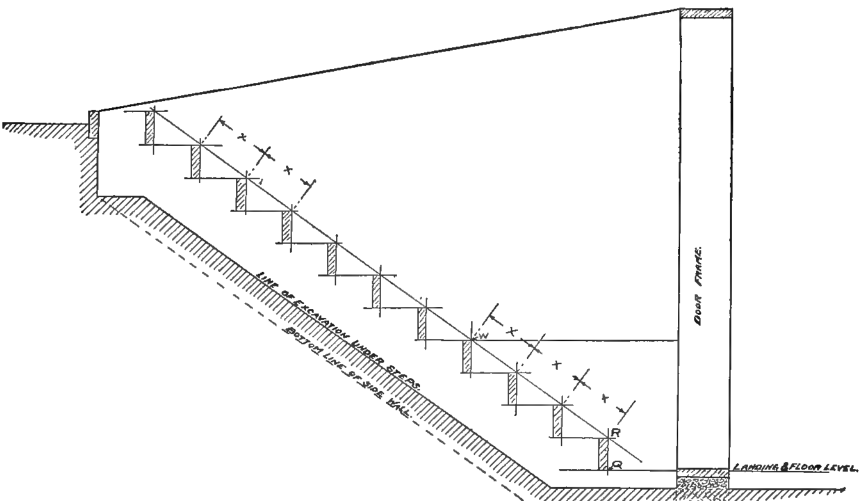


Figure 24. **Method of laying out basement steps**

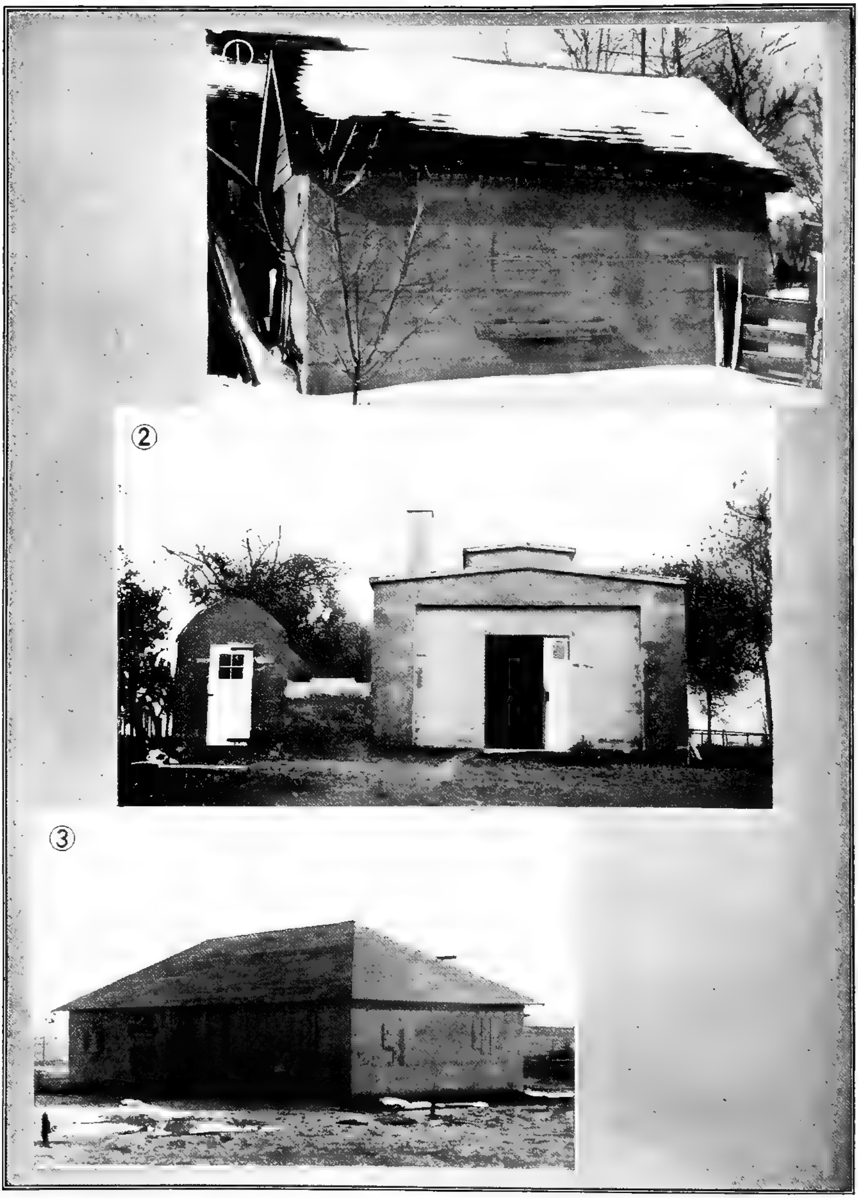


Figure 25. CONCRETE FARM BUILDINGS.

(1) Concrete Building on Farm of E. P. Barringer, Ruthven, Iowa, which serves the purpose of a bee house, smoke house and safety deposit vault combined.

(2) Concrete Smoke and Slaughter House, Gedney Farms, White Plains, N. Y.

(3) Ranch House of George Lee Tenney, near Grover, Colorado. The house is shown closed up for the winter, the owner occupying the ranch only during the summer. Mr. Tenney has several other examples of good concrete work on his place.

placed. It will be noted that the upper ends of the vertical pieces supporting the cross-forms are nailed to pieces which are held tightly against the walls by braces between them. This frame should be built in place, as better results will be obtained than if placed after building.

Walls for Concrete Farm Buildings*

SEVERAL types of concrete walls are successfully used for farm buildings, each type having its particular advantage, while all possess in common the general advantages of concrete construction. Monolithic walls are built either plain or reinforced. Block walls are built of hollow or solid block or frequently of concrete tile where this product is obtainable. Another type of wall is constructed of concrete posts or columns, and slabs cast in forms on the ground and afterwards assembled. Plaster walls are built with three or more coats of cement plaster applied to metal lath. All of these types will be discussed and suggestions for their construction given.

*Limited to walls of one story structures.

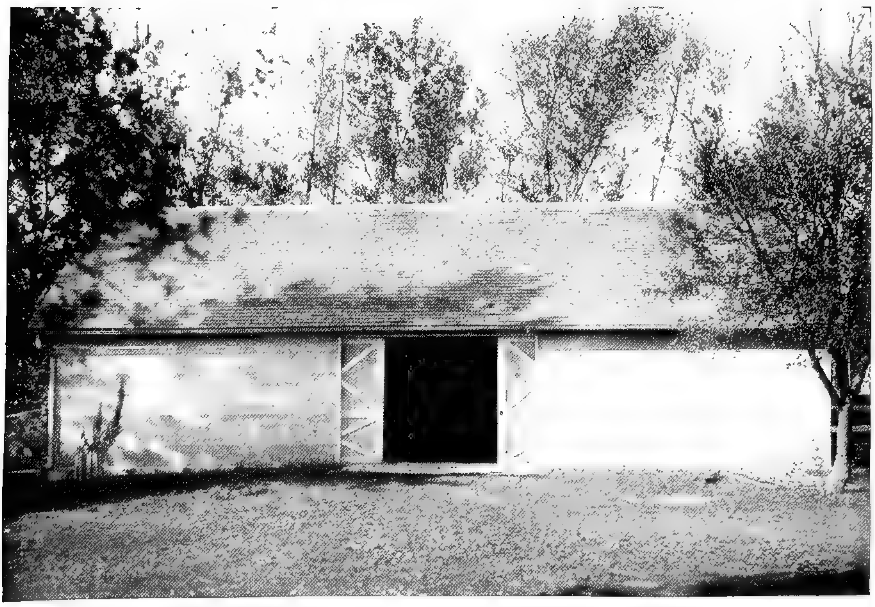
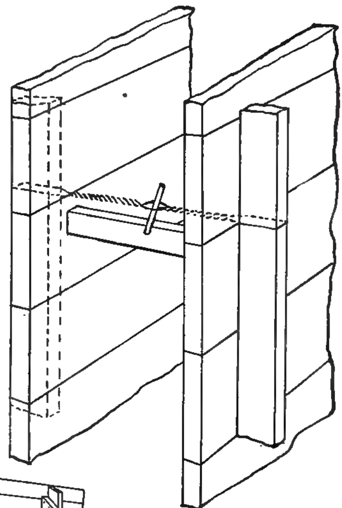


Figure 26. **Implement House, Echo Valley Farm, Odeboldt, Iowa. A substantial and pleasing structure with ample capacity for the farm implements and tools. Dimensions, 24 feet by 48 feet.**

Monolithic Walls*

MONOLITHIC or solid concrete walls are built single, or double with an air space. The single walls are recommended for all structures except ice houses. Except for the building of the forms, single monolithic walls of moderate height require practically no skilled labor. The lumber used for the forms, if carefully handled, is available for some other purpose. Double walls consist simply of two single walls, usually built up simultaneously, with a small air space between. This air space is made as narrow as can be constructed conveniently, the width generally being from three to six inches. Monolithic walls permit of a wide variety in design, and in this construction irregular shapes may be made without limit, depending upon the skill of the builder in providing the necessary forms. The essentials for building good monolithic walls are: Well made, substantial forms, properly proportioned and thoroughly mixed materials, and care in placing the concrete in the forms and protecting it until hardened.



*The word "monolithic" coming from "mono" meaning one, and "lith" meaning stone, is used in concrete work to denote the objects of concrete which are one continuous solid mass, or "as one stone."

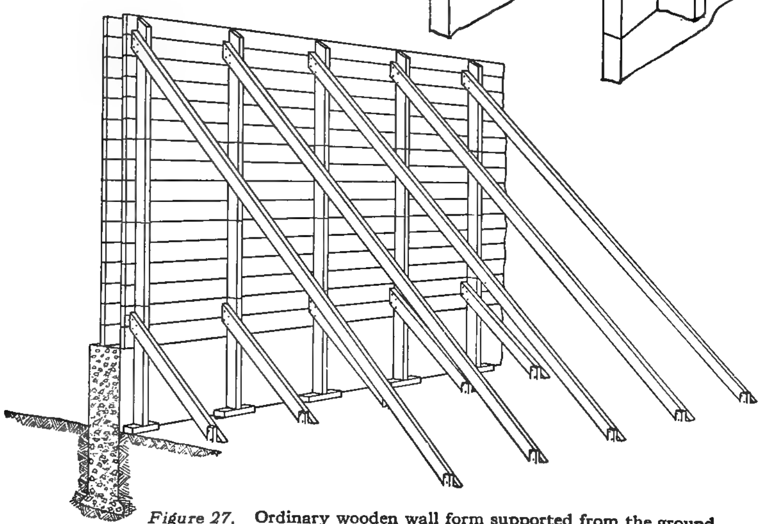


Figure 27. Ordinary wooden wall form supported from the ground and method of spacing forms.

Forms for Single-Wall Monolithic Work. There are two general types of forms available for the construction of monolithic concrete walls; wood forms built for a large section or the entire wall before concreting is begun, and wood or metal portable forms which are erected in sections as the work progresses. Forms of the former type are built in place and are supported by framing from the ground. If carefully handled the lumber in such forms need not be damaged but may be used for some other purpose later. Forms of the latter type are supported by the wall. They may often be purchased from the manufacturers but where constructed of wood, they may be built at home. These forms can be used a number of times and may quickly be removed and reassembled. They make a large saving in the amount of lumber needed and for this reason are especially recommended to the farmer.

In the selection of lumber for the construction of forms white pine is considered the best, but for work of minor importance, the cheaper kinds, such as spruce, fir and Norway pine, may be used. Stiff lumber is best adapted for struts and braces. All lumber to be used in the face of the forms should be free from loose knots and tendency to sliver, and should be surfaced on one side and both edges. For smooth work tongue and grooved stuff will give the best results.

For wall forms, two-inch stuff is recommended as lighter material springs out of alignment easily and requires closer spacing of studding. The lighter lumber also warps badly and is soon inconvenient to handle.

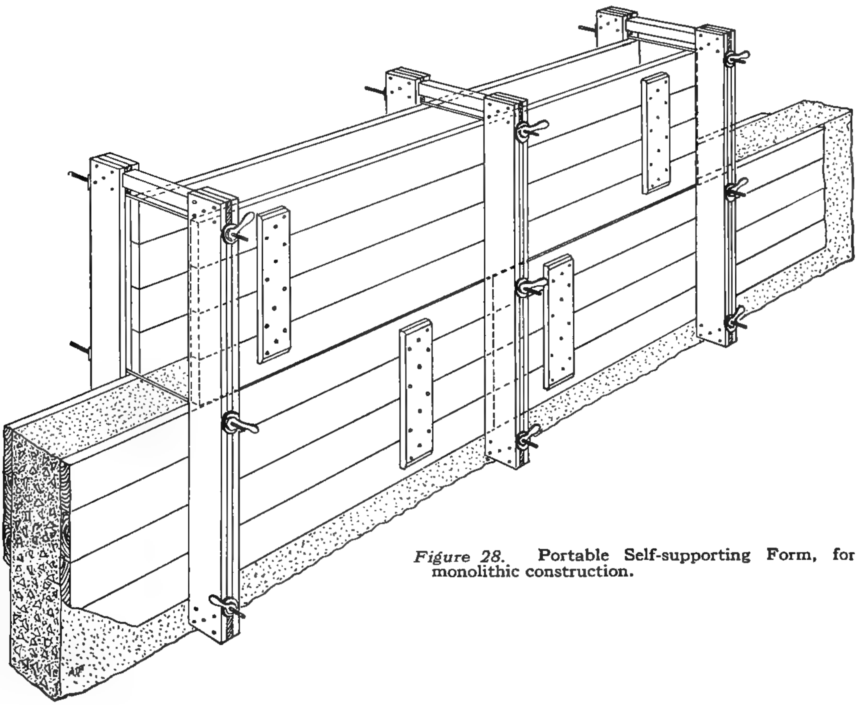


Figure 28. **Portable Self-supporting Form, for monolithic construction.**

For ordinary wall forms, two-inch lumber requires studding spaced about three feet apart. The construction of forms in the field should be planned carefully so that the lumber will cut with the smallest waste. The form boards require only light nailing to the studding, as the outward pressure of the concrete will hold them in place as soon as the forms have been filled. A uniform distance between forms is maintained by separators, and twisted wires passed around the studding as shown in Figure 27, upper view.

Forms for Double Wall or Hollow Wall Monolithic Work. In the construction of buildings such as ice houses, where it is necessary that good insulation against heat be provided, double wall or hollow wall monolithic work is often preferred. Double wall work, as the name implies, consists of two entirely separate walls, one constructed outside the other with a space between. To construct double wall monolithic work a special type of wall form is required unless the air space is sufficiently wide to accommodate two single wall forms back to back. The hollow wall may be constructed with the aid of cores placed in the forms and later withdrawn, or by placing in the center of the wall, tile or other similar material capable of producing an air space.

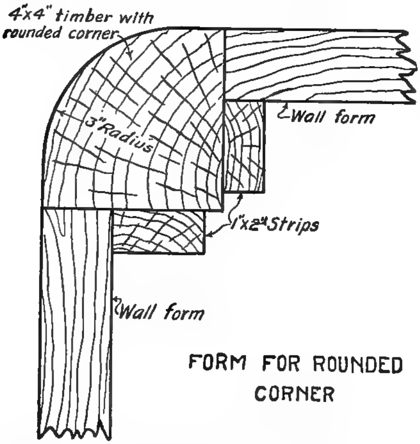


Figure 29. Form for rounding the inner corners of building walls. Rounded corners prevent the accumulation of dirt and simplify cleaning.

Double Wall Forms. The work of building the double walls is simplified if the height of wall built each day is limited to 2 or 3 feet. With this limitation, an ordinary portable or self-supporting wall form may be used for the inside of the inner wall and for the outside of the outer wall, while for the forms between the walls, small sections made up of one-inch stuff nailed to the flat side of 2 x 4's will generally suffice if held apart by some type of convenient spacers. The sections should be made up in sizes which will conform to the outer forms, and should be planned carefully so as to expedite removing from the walls and handling.

A convenient type of inner form spacer is shown in Figure 30. The spacer may be made of 2 x 4-inch material sawed through diagonally as shown, and held together by small stove bolts traveling in slots. The sides of the spacers are held to one of the inner forms by pegs which rest in screw eyes. The inner forms are then spaced at proper distances apart by the wooden spacers between the inner and outer forms, the wedges of the spacers are driven down into position and the nuts on the stove bolts tightened. As soon as the concrete in the walls is sufficiently strong the stove bolts are loosened, the wedges driven up, and the spacers removed. The forms can then be pulled off easily if they

were properly painted with whitewash or crude oil before placing in position.

Runways and Scaffolding. For the walls of one-story farm buildings, the most convenient method of lifting the concrete is by bucket or wheelbarrow. The latter method should be used if the work is very extensive, but for small jobs, buckets may suffice. Runways must be constructed strongly, with easy grades. Avoid sharp turns, and make runs at least 20 inches wide where above the ground, always lapping the right way. Where considerable work is being done, at least two wheelbarrows should be provided, so that the concrete may be placed as rapidly as possible. Wheelbarrows with metal bodies are handier and more durable than the wooden ones. Wheelbarrows must be watertight, as water allowed to escape from the mass carries cement with it.

The arrangement of scaffolding and runways must depend to a certain extent upon the methods of mixing used. Where the work is done by hand the mixing board may be moved around and kept conveniently close to the spot where the concrete is being used; if a mechanical mixer be employed, a good central location must be selected, and runways laid out so as to provide easy access to the mixer from all parts of the work.

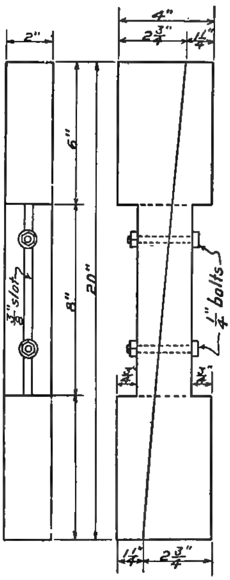


Figure 30. Adjustable Spacing Block used to keep forms for inner and outer walls at proper distance apart and to facilitate removal of the inner forms, double monolithic construction.

Preparation of Forms. Form boards which have been used before must have all concrete well cleaned from faces and edges. By painting the faces with whitewash, crude oil or a mixture of equal parts of linseed oil and kerosene, the concrete is prevented from sticking and the forms are protected. It is important that forms for window and door openings be prepared properly to prevent sticking. Attention to this matter will save much labor and breakage in removing the forms, and is especially important where the forms are to be used several times. If the boards in the face of the forms contain knot holes, these must be covered on the outside with a board, and patched up with sticky clay or other similar material just before the forms are filled. The clay must be applied from the inside, and trowelled to give a smooth surface. Knot holes are sometimes covered with small pieces of tin tacked on the inside face of the boards, but where this is done the imprint of the tin patch is left in the wall.

Forms must be as nearly watertight as possible. Where the water is allowed to escape from the mixture, it invariably carries with it a considerable quantity of cement. Cracks between the boards often leave room for the mortar to squeeze through, producing fins or unsightly lines on the face of the wall. Sharp corners are hard to fill and are easily broken after the removal of the forms; therefore, they should be

avoided by the use of fillets. Where the forms are held at proper distance by wires, these should be amply strong, as the breaking of a wire will allow the wall to bulge at that point.

Joining Old Work. The ideal way of constructing monolithic concrete walls is by one continuous operation, but in most cases this is impossible. Whenever concreting is interrupted, even for an hour, a weakened bond will occur between the new concrete and that previously placed unless special precautions are taken. Without these precautions, clearly defined joints or cracks are apt to develop. Frequently the work can be divided into sections that can be completed without interruption, thus avoiding horizontal joints and creating vertical ones where they will not weaken the structure nor detract from its appearance. To accomplish this, the forms should be erected in sections, or a board should be set up in the form, making a complete partition. So that the sections of the wall will be keyed into each other, a groove should be formed in both ends of the first section, and thereafter in one end of each section. Such a groove can be made as shown in Figure 31, by placing a 2 x 4 vertically against the wall or partition in the form. Previous to placing, the edges of the 2 x 4 should be dressed so as to make it possible to remove it without destroying or marring the groove. In the course of construction, the next section will be concreted against the first and the groove will be filled with concrete, thus keying the two sections together.

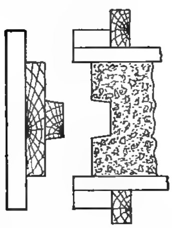


Figure 31. Method of joining foundation walls where it is necessary to leave an expansion joint or where concreting has been discontinued for any reason.

In building up a wall the concrete in the section under construction should be kept at the same level as far as possible. If for any reason, fresh concrete is to be placed on concrete even partially hardened, the surface to be built upon should be thoroughly drenched and then covered with a grout made by mixing cement with water to the consistency of cream, immediately before concreting is resumed. Concreting should be resumed immediately after the grout is applied and before it shows any signs of drying. The amount of water that will be required in dampening the old concrete will depend upon a number of conditions, but its tendency to absorb water must be satisfied; otherwise the water will be absorbed from the grout which will make it worthless, and defeat the object of its use.

All foreign matter, such as loose sand, straw, chaff, leaves, etc., must be removed from hardened or partially hardened concrete before work is resumed.

Removing the Forms. Haste in removing forms from the work often leaves the wall without proper protection from the weather, as well as from loads or stresses to which the walls may be subjected. In cold weather concrete hardens slower than in warm weather. It is impossible to lay down a definite rule for the removal of forms and other conditions from concrete work. In general, it may be stated that forms can be removed from concrete walls provided they are not to be loaded immediately, as soon as they obtain sufficient strength to retain their

shape and permit of continuing the work without damage to the concrete in place. The saving of a small amount of time does not compensate for the risk of removing the forms too soon. Do not mistake a frozen wall for one in which the concrete has hardened. In removing or taking down the forms care must be taken not to damage the work. The forms should be well oiled or whitewashed as previously suggested so that the smallest possible amount of prying and bar work will be necessary. After removing forms held together by wires, as shown in Figure 27, the ends of the wire may be cut off flush with the surface of the wall, or if some finish is to be applied, the wires should be broken off an inch below the surface to prevent discoloration of the wall from rust.

Surface Finish. If the forms are built of smooth, dressed lumber, carefully manipulated so as to avoid marring and the concrete be placed wet enough to be quaky, and is then well spaded, the walls should require no further treatment. If a stucco finish is desired it may be secured as directed on page 52, in the chapter on "Cement Plaster Walls." It is not generally advisable to paint the surface of walls with cement and water grout for this often scales off.

Figure 32. Monolithic Blacksmith Shop, Echo Valley Farm, Odeboldt, Iowa. A convenient building equipped to take care of horse shoeing, wagon and implement repairs, and other forge and machine work required about the farm. Dimensions, 16 feet by 18 feet. Built by the owner, 1908.

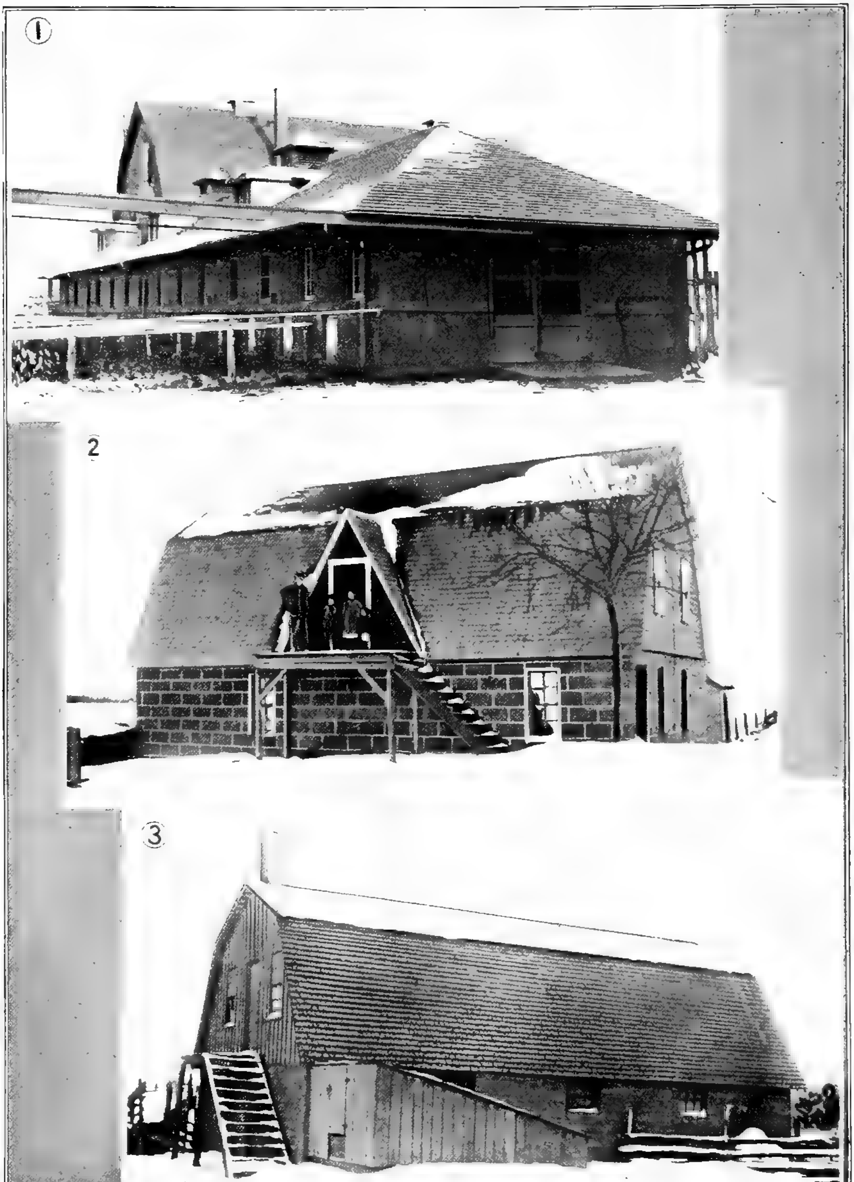


Figure 33. CONCRETE HOG HOUSES.

(1) Col. J. Watson French's Hog House, Davenport, Iowa. Combination concrete and tile.

(2) Concrete Block Hog and Chicken House of Fred Kolbert, Harbor Beach, Michigan.

(3) Hog House of John Hunt, Bad Axe, Michigan. Type of concrete farm building common in Northern Michigan.

Wall Reinforcing

WALL reinforcing for small buildings, although a comparatively simple matter, is one which should receive careful attention. The functions of reinforcing metal in such walls are (1) to prevent cracks due to settlement and (2) to prevent cracks due to expansion and contraction from heat and cold. In low structures such as those discussed in this volume, the live load imposed upon the walls is seldom, if ever, great enough to require reinforcing and the wind load need not be considered.

It will generally be found satisfactory to reinforce the walls of one story buildings with a net work of vertical and horizontal rods placed in the centre of the wall. In double wall work each of the walls must be reinforced independently just as though the two walls were entirely separate. The reinforcing rods may be round, square, twisted square, or of special section so long as they have a sufficient effective cross-sectional area. In addition to the rods placed in the body of the wall, special reinforcing is required around all window and other openings and at all corners as described in later photographs. "Triangle Mesh" and similar reinforcing fabrics are sometimes substituted for reinforcing rods and there is no objection to their use if fabric used has a cross section at least equal to that of the reinforcing rods which would occupy the same area.

Such material as barbed wire, worn out fencing ,and scrap iron must be avoided if the builder would feel sure of satisfactory work. The object of reinforcing is to secure strength, and for such a purpose, weak or badly rusted steel is obviously unsuited. Reinforcing rods which

Figure 34. Concrete Granary, Morgan Farm, Beloit, Wisconsin. This granary has a double row of wide bins, with a wide driveway up the middle. The floor and walls are of concrete.

have become rusty enough to scale must be cleaned off before placing in the wall, as the scale prevents the concrete from obtaining a firm grip on the metal. For removing scale, a stiff wire brush will be found well suited.

Size and Spacing of Rods. The following sizes and spacing of reinforcing rods is recommended: For walls less than 8 inches in thickness, use 3/8 inch round rods, spaced 24 inches apart, center to center, both vertically and horizontally. For walls 8 inches to 10 inches in thickness, use 1/2-inch round rods spaced 24 inches apart, center to center, both vertically and horizontally. For walls wider than 10 inches, two systems of 3/8 inch reinforcing rods near the inside and outside of the wall should be substituted for the one system at the center. Where two systems are required, the rods should be placed about 1 inch in from the inner and outer faces of the wall.

Rods should be wired together rigidly at all intersections, and the ends of the rods lapped a distance to equal 64 times the diameter of the rod, which, in the case of 3/8 inch rod, is 24 inches and for 1/2 inch rod is 32 inches. The reinforcing network should not be broken at any point, except for doors, windows, or other openings. To start the reinforcing, the vertical rods should be imbedded 18 inches to two feet in the foundation. The lowest horizontal rod should then be wired to the vertical rods, all around the building, at the ground level. Additional lengths of vertical rods are wired on as required, and the remaining bands of horizontal reinforcing placed as the work progresses.

Corner Reinforcing. All corners and openings require special methods of reinforcing. A simple and effective scheme for reinforcing corners is shown in Figure 36. Instead of being bent at the corners,

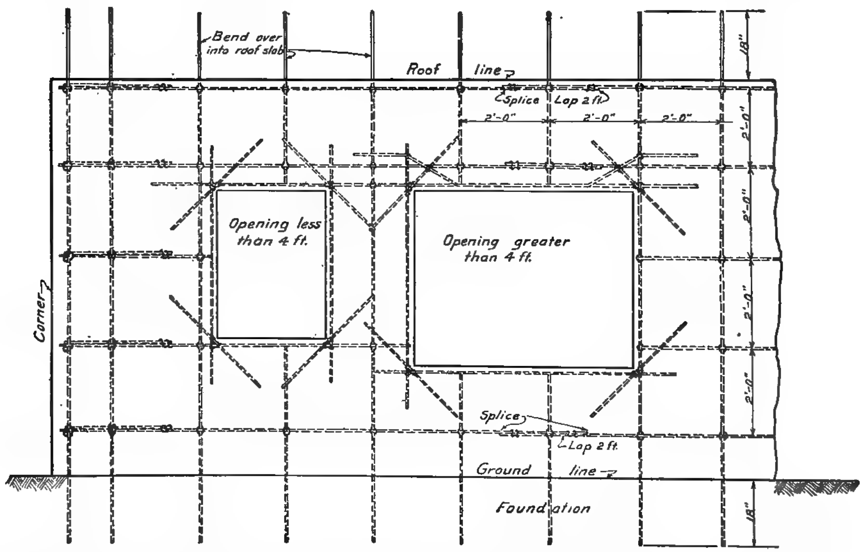


Figure 35. Diagram showing the general scheme for reinforcing monolithic walls for small buildings limited to one story in height.

which is a rather difficult job for long bars, the horizontal reinforcing rods are terminated and securely wired to a vertical rod at this point. Additional rods about 58 inches in length, bent to a right angle with equal legs, are used to reinforce the corner horizontally. These rods should be bent on a 6-inch radius, making the straight section of each leg about 24 inches long, the length required for good lap with the horizontal reinforcing, to which the corner reinforcing should be wired. For the corner reinforcing, 3/8-inch round rod or its equivalent in cross-sectional area, should be used.

Window and Door Openings. For all openings less than 4 feet in width, the system of reinforcing shown in Figure 37 is recommended. 3/8-inch round rods are used. Two rods are placed vertically on each side of the opening, two rods are placed horizontally below the opening, and three rods above the opening. Two rods are also placed diagonally across all corners of the opening as shown in the figure. Reinforcing rods placed above openings should be 3 feet longer than the width of the opening, while those on each side of, and below openings, should be at least 18 inches to 2 feet longer than the dimension of the opening in the direction parallel to the rods. Diagonal rods should be 2 feet to 3 feet in length.

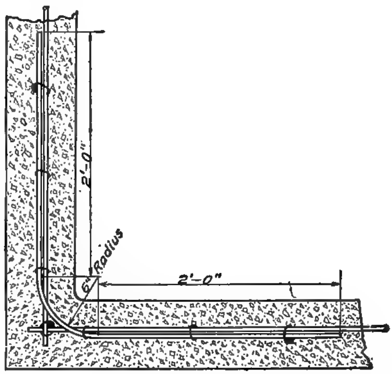


Figure 36. Method of reinforcing corner of monolithic buildings.

Where door or window openings are more than 4 feet in width, it is advisable to modify the above scheme by bending up the ends of two of the rods above the opening as shown in Figure 38. This serves to take care of the large shear load which might otherwise unduly stress the concrete near the ends of the span. If the opening is 8 feet or more in width, the wall above should be strengthened still further by substituting 1/2-inch rods for the 3/8-inch rods recommended for smaller spans.

Calculating the Amount of Rods Required. It is a simple matter to figure out, fairly accurately, the amount of reinforcing rods required for the walls of any simple farm building. The number of rods needed for the vertical reinforcing equals one-half the perimeter of the building in feet, and for the horizontal reinforcing, one-half the height of the wall in feet multiplied by the number of rods in each course of horizontal reinforcing. Four corners require about 10 feet of extra rod per foot in height. The extra reinforcing metal around the windows and doors varies, of course, with the size of the opening. Reinforcing rod is sold by the pound, and generally comes in stock lengths from 12 feet to 30 feet. The area, weight per foot, and number of feet per pound of the commoner sizes of square and round reinforcing rods are given in the following table:

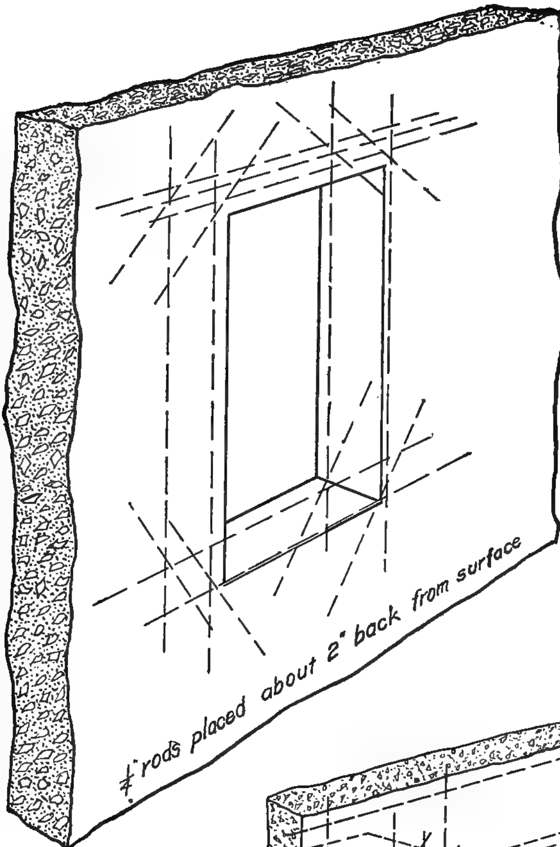


Figure 37. Method of placing reinforcing rods around wall openings less than 4 feet in Width.

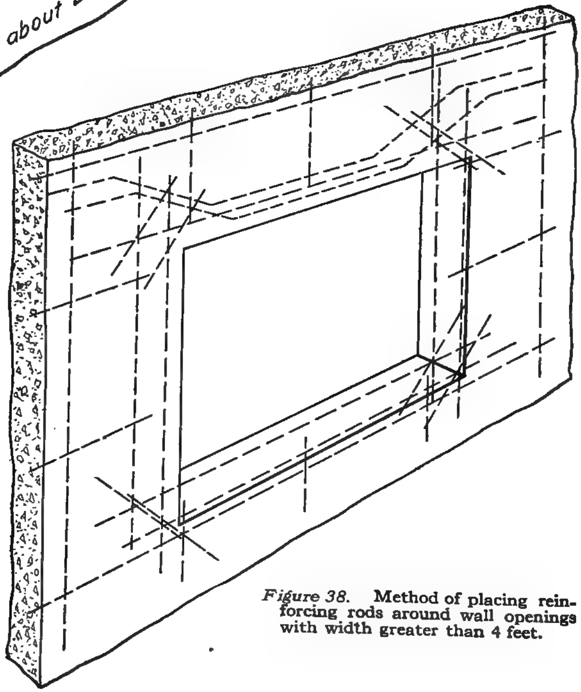


Figure 38. Method of placing reinforcing rods around wall openings with width greater than 4 feet.

Table B

Size	Area Square Rod	Weight of Square Rod 1 Ft. Long	Length of 1 Lb. of Square Rod	Area of Round Rod	Weight of Round Rod 1 Ft. Long	Length of 1 Lb. of Round Rod
¼	.0625 Sq. In.	.212 Lbs.	4.720 Ft.	.0491 Sq. In.	.167 Lbs.	6.000 Ft.
5/16	.0977 Sq. In.	.333 Lbs.	3.000 Ft.	.0767 Sq. In.	.261 Lbs.	3.830 Ft.
⅜	.1406 Sq. In.	.478 Lbs.	2.090 Ft.	.1104 Sq. In.	.375 Lbs.	2.665 Ft.
7/16	.1914 Sq. In.	.651 Lbs.	1.530 Ft.	.1503 Sq. In.	.511 Lbs.	1.957 Ft.
½	.2500 Sq. In.	.850 Lbs.	1.175 Ft.	.1963 Sq. In.	.667 Lbs.	1.500 Ft.
9/16	.3164 Sq. In.	1.076 Lbs.	.930 Ft.	.2485 Sq. In.	.845 Lbs.	1.182 Ft.
⅝	.3906 Sq. In.	1.328 Lbs.	.752 Ft.	.3068 Sq. In.	1.043 Lbs.	.958 Ft.
¾	.5625 Sq. In.	1.913 Lbs.	.523 Ft.	.4418 Sq. In.	1.502 Lbs.	.665 Ft.
⅞	.7656 Sq. In.	2.603 Lbs.	.384 Ft.	.6013 Sq. In.	2.044 Lbs.	.489 Ft.
1	1.0000 Sq. In.	3.400 Lbs.	.294 Ft.	.7854 Sq. In.	2.670 Lbs.	.375 Ft.

Table C

TABLE OF AREAS OF ROUND REINFORCING RODS AND WIRE

Diameter in Inches	A. S & W. Gauge	Diameter in Decimals of an inch	Area in Square Inches of Round Rod or Wire	Area in Square Inches of Square Rods
1	...	1.000	.785	1.000
⅞	...	.875	.602	.766
¾	...	.750	.442	.563
⅝	...	.625	.307	.391
½	...	.500	.196	.250
...	7/0	.490	.189	......
...	6/0	.460	.166	.....
7/16	...	.437	.150	.191
...	5/0	.430	.145	.....
...	4/0	.393	.121	.....
⅜	...	.375	.110	.141
...	3/0	.362	.103	.....
...	2/0	.331	.086	.....
5/16	...	.312	.076	.098
...	0	.307	.074	.....
...	1	.283	.063	.....
...	2	.265	.054	.....
¼	..	.250	.049	.063
...	3	.244	.047	.....
...	4	.225	.040	.....
...	5	.207	.034	.....
...	6	.192	.029	.....
3/16	...	.187	.027	.....
...	7	.177	.025	.....
...	8	.162	.020	.....
...	9	.148	.017	.....
...	10	.135	.014	.....
⅛	...	.125	.012	.....
...	11	.120	.011	.....
...	12	.105	.008	.....

Cutting and Bending Rods. The simplest manner of cutting small reinforcing rods is by means of a cold cut or chisel on an anvil or heavy piece of steel. Rods are sometimes cut up with a hack saw, but this method is somewhat slower. After indenting the rod all around with a chisel or cutting in a small distance with a saw, the end of the rod may be placed in some convenient device for holding it, while the opposite end is bent back and forth until the fracture occurs. Where there are a large number of rods required, as is the case when several buildings are to be erected, it is sometimes economical to invest in large bench shears, thus materially reducing the time required to cut the rods.

Single bends or angles in moderate sized rods are simple to make and hardly require explanation. Where three or four bends must be made some difficulty may be encountered in getting them all in the desired plane and at proper angle. The proper angles can generally be obtained quite easily by first marking off the desired shape of the rods on a board floor or top of a heavy bench and then nailing on substantial cleats in such a manner that the rods, when bent up between these cleats, will have the required angles. To prevent the rods from bending out of plane, clamps may also be required. In cases where there are a considerable number of rods to be bent, it may be economical to have the work done by a local blacksmith or secure a small bending machine, obtainable at moderate expense.

Walls Without Reinforcing. Short walls of excessive width and limited height are very often built without reinforcing. They are generally satisfactory for the first floor of low barns and similar work. Walls constructed without reinforcing should not be less than 12 inches in width. The height should be limited to 12 feet, and the length of each section of the wall should be limited to 30 feet. An expansion joint must be left between each section, as explained on page 36.

Figure 39. Iowana Farm, Davenport, Iowa, Col. J. Watson French, proprietor. The silos are of monolithic concrete. All of the buildings on the place are built of a combination of concrete and tile. Tri-City Construction Company, Davenport, Contractors.

Concrete Block Walls

CONCRETE block walls have found general favor because of their pleasing appearance, economy in construction, and also for the reason that the blocks may be made at odd times. Walls of this type can be made in a variety of face designs without the use of forms. Hollow block walls of a given size require but two-thirds the amount of material necessary for solid walls of the same dimensions, and the air spaces in hollow blocks interrupt the passage of heat and cold.

Concrete Blocks. For the sake of uniformity in appearance, blocks for a given piece of work should be made with the same materials, proportions, and amount of water. The blocks should also be cured under the same conditions. These precautions are necessary to insure uniform quality and color. The plain faces, either tooled or panelled, or broken ashlar designs are recommended in preference to the more common rock face which often presents an artificial appearance.

In the design of concrete block buildings the dimensions of the blocks available should be taken into consideration, and the plans so made that the walls may be built as nearly complete as possible with whole and half blocks, avoiding fractional sizes.

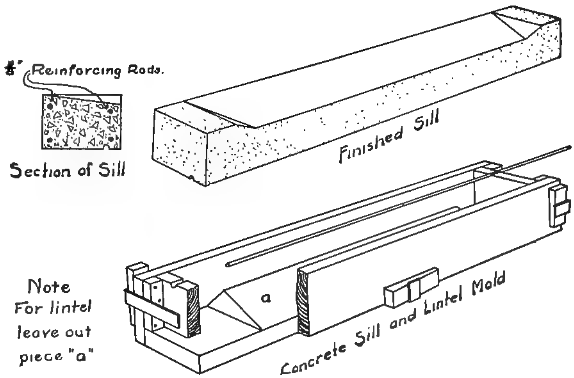


Figure 40. Mold Box for Casting Sills and Lintels, face down, and Finished Sill.

Concrete Sills and Lintels. Concrete sills and caps may conveniently be used in walls made of any material, as these are easy and inexpensive to make in any desired size. Most block dealers carry such sills and caps in stock or have equipment for making them. If they cannot be purchased they can be moulded in simple wooden forms similar to that shown in Figure 40. This form will make sills of any length, casting them face down. Proper slope is given to the top of the sill by tapered board (a). The pallet and sides of the mold should be dressed, covered with varnish or shellac, so as to give the sill a smooth surface, free from marks showing the grain of the lumber. By removing this, the form is made suitable for casting lintels or caps. A mixture of 1 part cement to 2 parts coarse sand, to 3 parts small stone aggregate, will be found satisfactory, enough water being used to make the mass quaky. The mold should be filled up with the 1:2:3 concrete, and tapped with a hammer or jarred to compact the mass and force out the air.

The bottom of the sill may be smoothed off with a wooden straight edge. The width of sill must be about $1\frac{1}{2}$ inches greater than the thickness of the wall. Form marks and other irregularities can be removed by rubbing with a concrete brick made of one part cement to two parts sand.

Laying Concrete Block Walls. The rules for laying block walls are simple. The "knack" of doing neat and rapid work is not hard to acquire. The equipment necessary consists of a mortar mixing box, 3 feet by 5 feet, mortar board 30 inches by 30 inches made of 1-inch lumber, planed on one side and both edges and held together by two or three cleats; also a trowel, hand level, straight edge and plumb board. All blocks must be drenched with water before being used or the moisture will be drawn from the mortar. The first course of block should be laid upon a mortar joint fluctuating in thickness so that regardless of any irregularities in the blocks the course will be absolutely level. The blocks, which have previously been drenched, are laid in a quarter-inch bed of cement mortar. A quarter-inch mortar joint is also placed between the ends of abutting blocks. Each course is begun at the corners and laid toward the middle of the wall. The blocks should be laid level and kept in perfect alignment. Good alignment is maintained by working strictly to a line, stretched over the outer edge of the wall on the same level with the top of the blocks being laid. The wall should be tested frequently by placing the plumb level against it to see that it is perpendicular.

If a concrete roof is to be placed on a concrete block building, the top course of blocks must either be cast without air spaces, or the air

Figure 41. Monolithic Milk House and Tank, Funk Farms, Shirley, Illinois. Mr. Funk also has a concrete hog house and several concrete silos.

spaces must be filled up with concrete before the blocks are laid. If the latter method is used, the blocks may conveniently be laid down on a concrete or other flat surface with the air spaces in a vertical position, and the latter filled with slush concrete. If it is desired to build a concrete roof upon a concrete block building which has been up for some time, it may be found convenient to lay small sections of sheet iron or similar material over the air spaces in the blocks to prevent the concrete from running through.

Good cement mortar is made in proportions of 1 part cement and 2 parts sand mixed with enough water to make it of the required consistency. Regardless of the care taken in the preparation of the mortar, it will be practically destroyed by being robbed of its moisture, unless the blocks are damp when placed. Cement mortar starts to harden very soon, and for this reason only such quantities as will be used within half an hour should be mixed.

Table D

NUMBER OF STANDARD SIZE CONCRETE BLOCK NECESSARY PER LINEAR FOOT OF WALL

Height of Wall	Number of Blocks per Linear Ft.	Height of Wall	Number of Blocks per Linear Ft.	Height of Wall	Number of Blocks per Linear Ft.
2 ft.	2.25	6 ft.	6.75	9 ft. 4 in.	10.50
2 ft. 8 in.	3.00	6 ft. 8 in.	7.50	10 ft.	11.25
3 ft. 4 in.	3.75	7 ft. 4 in.	8.25	10 ft. 8 in.	12.00
4 ft.	4.50	8 ft.	9.00	11 ft. 4 in.	12.75
4 ft. 8 in.	5.25	8 ft. 8 in.	9.75	12 ft.	13.50
5 ft. 4 in.	6.00				

NOTE—These blocks are 7¾ inches high, by 15¾ inches long, by 8 inches in width, which makes them 8 inches high, 16 inches long and 8 inches in width in the wall. This allows for a quarter inch of mortar around each block.

Unit Column and Slab Walls

Method of Construction. In slab or panel wall construction, the individual wall sections and the posts or columns are cast separately on the ground and when properly hardened, are assembled so as to form a complete wall. This construction is well suited to low buildings such as cattle and implement sheds, poultry houses, piggeries, etc. The slabs are held in place by columns or posts recessed to receive them as illustrated by Figure 42. These recesses are formed by attaching to the sides of the mold, strips of wood, the dimensions of which are the same as those of the recesses required. Slabs may be made to weigh as much as 600 pounds, although they are more conveniently handled if made lighter. The weight of a slab 2 inches thick 2 feet wide and 8 feet long is 400 pounds. Although the thickness may vary somewhat, the length should not be over 8 feet. Two feet is a convenient width, but with a short length a greater width may be used.

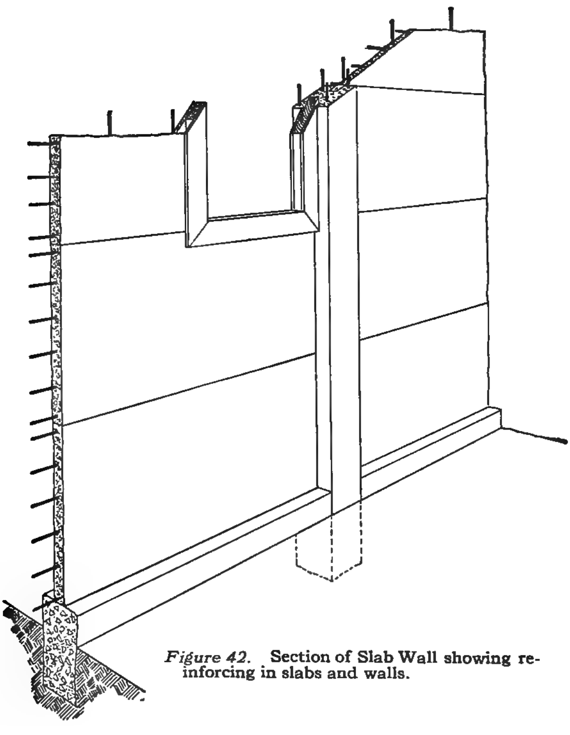


Figure 42. Section of Slab Wall showing reinforcing in slabs and walls.

Columns are required on each side of door or window openings to hold the slabs in line; however, with small windows, where the depth is not greater than the width of one slab, a wooden window frame is sufficient. Where possible, it is well to place the opening next to columns, for by this arrangement only one extra column is necessary for long openings; and for small windows the end of only one slab need be held in line by the window frame.

The Columns. The general shape of the column mold is illustrated by Figure 107 page 122. Molds should be made of 2-inch material and well braced at the center to prevent bulging. Pallets are not necessary for the line column molds, as the cores are placed on the two opposite sides. The corner columns must be made on a pallet as they are recessed on two adjacent sides, the cores for one recess being fastened

to the pallet, while the other is fastened to one side of the mold. The cores should be beveled one-eighth of an inch on each side, so that they can be drawn from the columns without injury to them. Where slabs 2 inches in thickness are used, line columns should be 7 inches square. Columns having two adjacent sides recessed should be 8 inches square, however, in order to give ample section of concrete between recesses. Care should be taken that the recesses in the heavier columns are placed the same distance from the exterior surface as those in the lighter columns.

The reinforcing consists of four ¾ inch rods, held together with soft iron wire ties spaced about 12 inches apart along the reinforcement. Concrete for the columns is mixed in the proportion of 1 part cement, to 2 parts clean, coarse sand, to 3 parts screened gravel not to exceed ¾ inch in size. The reinforcing rods in two corners diagonally opposite should be allowed to project about 3 inches from one end of the column; this may be accomplished by boring holes in the end of the molds and allowing the rods to project through. When the columns are set up, these rods will be grouted into holes drilled in the floor or foundation wall.

Concrete posts set 40 inches in the ground may be used instead of columns. These posts should be of the same cross section and recessed in the same way as the columns, excepting that they are 40 inches longer to provide for placing in the ground. For this construction a concrete curb of the same width as the posts should be placed between them to furnish proper support for the slabs. The curb must be built on firm soil, being about 18 inches in height, and extending not over 6 inches above ground.

The Panels or Slabs. Forms for the slabs are made of lumber 4 inches wide and of the same thickness as the slabs. The side pieces are cut two feet longer than the length of the required slab to provide for cleats to hold the end pieces, which are cut to the same length as the width of the slab. The sides are wired together with No. 12 wires looped through ⅜-inch holes in the form and held by placing nails in the loops,

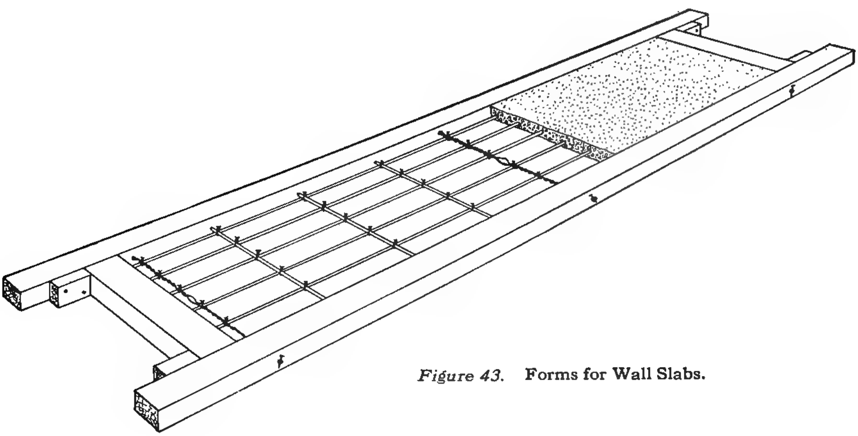


Figure 43. Forms for Wall Slabs.

as shown in Figure 43. Where slabs have a length of from 6 to 8 feet a tie wire is placed 2 inches from each end and one midway between.

The wires serve not only as ties, but also as the cross reinforcing at these points. The end ties are twisted until the sides are drawn tight against the end pieces and the middle then drawn as tight as possible without distorting the sides from a straight line. With shorter slabs, two tie wires will probably answer. These should be located so as to replace two of the reinforcing rods, and at the same time properly secure the form. After the tie wires have been twisted sufficiently tight, the long reinforcing rods are placed and wired to them with soft iron wire as shown in Figure 43. The form is then turned over and the cross rods are wired to the long ones. It is well to wire the reinforcing in a number of forms before starting to place the concrete, thus necessitating no interruption in the latter part of the work.

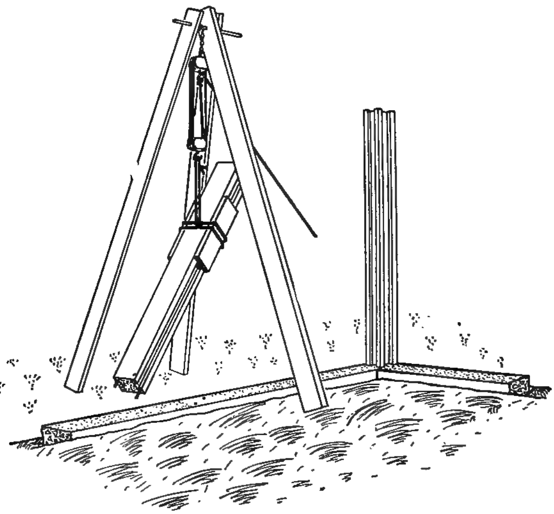


Figure 44. Tripod, Block and Tackle for lifting and placing columns and slabs.

With a smooth floor or platform available, the wall slabs may be cast directly upon it, or if the structure is to have a concrete floor this should be built first and when properly hardened will afford a convenient place for the making of slabs. In order to economize in floor space the slabs may be cast with a layer of paper to prevent the slabs from adhering to the floor or to each other.

For any size slab, up to 2 feet by 8 feet, the reinforcing should consist of ¼-inch round or square steel rods free from rust. Reinforcing rods must be placed one inch from each edge, the remaining horizontal rods being spaced about four inches apart, and the vertical rods twelve inches apart or less. The more closely spaced reinforcing must always be placed horizontally, and wider spaced reinforcing vertically, no matter whether the length of the slab extends in a horizontal or a vertical

direction. Thus, a slab made to be used in a horizontal position in the wall is not properly reinforced for use in a vertical position; the opposite is equally true.

The mixture used should be made of 1 part cement, 2½ parts clean, coarse sand and 2 parts gravel—the latter not to exceed one-half inch in size. If no gravel is used the proportion of sand may be increased to three parts. Enough water must be used to give a quaky consistency. Cement mortar is placed between the slabs and also in the recesses between columns and slabs, thus making a weather-tight wall. Before filling in these joints, the edges of the slabs and columns should be soaked thoroughly and painted with a cement grout.

Tripod and Tackle. The work of placing the columns and slabs in position is greatly simplified by the use of a tripod with block and tackle, as shown in Figure 44. The tripod can conveniently be made of 2 x 6 inch or 2 x 8 inch plank held together at the top by a large bolt or rod from which the block and tackle are suspended. In placing recessed columns or posts with the tackle it is advisable to protect the corners from injury by using wood between the concrete and the rope, as shown in the figure. No attempt should be made to place either columns or slabs until these are thoroughly cured, for the greatest strains on these members are carried while being placed in position.

Figure 45. Beach Farm Dairy, Coldwater, Michigan, Neal & Angevine, proprietors. Barns, silos, dairy house and other buildings are of monolithic concrete. The walls of all the structures except the silos are marked off in imitation of concrete blocks. The low building to the right is the dairy barn, which is ventilated by means of the two concrete stacks. R. C. Angevine, Coldwater, was the contractor.

Cement Plaster Walls

Method of Construction. Cement plaster construction offers one of the most convenient as well as economical methods of building concrete walls for small farm buildings. The framework for the support of the plaster walls should be constructed on concrete columns and beams, cast in mold boxes similar to that shown in Figure 107, on page 122. For ordinary low farm buildings, columns and beams 8 inches square may be considered standard, being reinforced with one round reinforcing rod near each corner. In general, where the length of the columns or beams does not exceed 8 feet, columns may be reinforced with four ⅜-inch round rods, and beams with four ½-inch round rods. Rods of shapes other than round may be used if equivalent in size, that is equal in cross sectional area.

A good method of securing the columns to the foundation or floor is described on page 49. Two reinforcing rods diagonally opposite should be allowed to extend 3 inches from the end of the columns, which is to be placed on the foundation as suggested under "Unit Slab and Panel Walls." A suitable method of joining columns and beams is shown in Figure 46. A 1½-inch round rod twelve inches long should be placed in the center of the top end of each column, being allowed to protrude up 6 or 7 inches. The purpose of these rods is to form pins by which the beams are secured to the columns.

All beams may be cast in the same mold box as the columns, small end cores being inserted to form the recesses in both ends of the beams as indicated in the illustration. Special attention should be given to joining the beams at the corners, and for this purpose the shaping as shown, of the ends of all beams at the corners, will be found convenient. No. 12 galvanized wires should be embedded in the outer face of the columns and beams at intervals of 10 to 12 inches, these being required

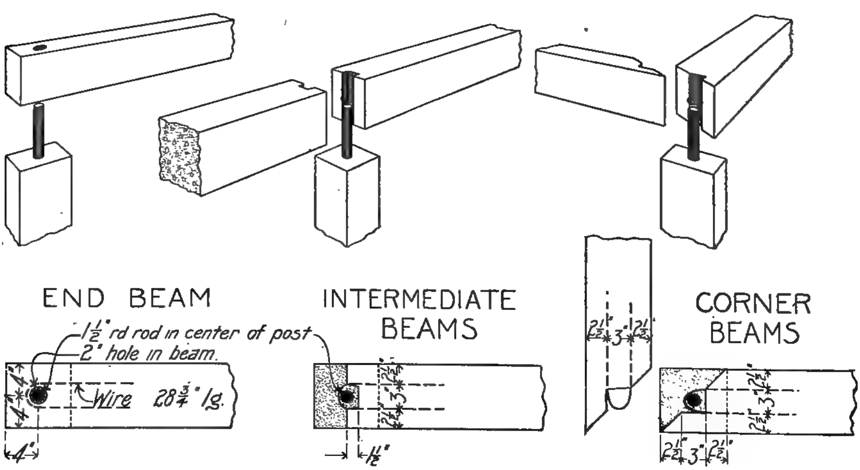


Figure 46. Method of joining end beam, intermediate beams and corner beams to column.

to hold the wire lath in place. After the beams are in place, the spaces at the joints should be filled with mortar, wet enough to flow readily to all parts of the joint, filling every crevice.

Metal Lath. Several types of metallic lath are obtainable. One type, made from slotted metal, is formed into a variety of shapes with different size openings and can be obtained in various weights; the lath is usually coated temporarily to protect the metal from rusting. This type of lath provides a good support for the first plaster coat because of the rough or uneven surfaces which catch and hold the plaster, but the cut edges of the metal have a tendency to rust where there is any dampness, unless the lath is thoroughly covered with plaster on both sides.

Another type, known as wire lath, is made from drawn wire, woven to form a network of fabric having 2½ meshes per inch. The lath is obtainable japanned or galvanized and with various sizes of wire; the best lath is one that has been galvanized after weaving, as the coating is thus more serviceable besides adding to the stiffness of the lath. While wire lath does not provide as good a support for the first plaster coat as slotted metal lath, the drawn surfaces show less tendency toward rusting. For straight walls, lath made from No. 18 wire is recommended, but for shaping cornices, etc., it is better to use the lighter wire (No. 21) as this can be bent more easily to the desired form.

Figure 47. An Attractive Concrete Barn on the farm of John Lindholm, St. Charles, Illinois. Dimensions, 20 feet by 30 feet inside. Cost, $600. This building contains a carriage and automobile room, stalls for one horse and three cows, a small granary, and a hay mow.

Applying the Lath. Care should be taken to stretch wire lath well over the framework, otherwise when applying the first plaster coat the lath will bend in places under the pressure of the trowel, thus interfering with the clinch of the plaster upon the mesh and giving the wall an uneven surface. Where metallic lath without stiffener is used, the columns should not be placed further apart than 4 feet; where it is desirable to place the columns at a greater distance apart, it is necessary that the lath be stiffened either by a system of vertical reinforcing rods or that lath with self-contained stiffeners be used. ½-inch reinforcing rods make suitable stiffeners when spaced 12 to 18 inches apart; extra

rods should be put in, however, around door and window openings, about 2 inches back from the surface. The lower ends of these rods may be grouted into holes drilled in the top of the foundation, while the top ends should be secured by the No. 12 wires placed in the beam. It is generally advisable to use one horizontal reinforcing rod as a tie for the vertical rods. The horizontal rod should be ½ inch in diameter, placed 2 to 3 inches below the window openings. The horizontal rods must be wired to the vertical rods at each intersection.

Metal lath should be lapped at least one inch wherever joined, and fastened to the columns and stiffeners in such a manner as to preclude the possibility of sagging or bulging. For fastening metal lath to the stiffeners, No. 18 soft wire galvanized, is recommended, although No. 16 plain soft wire may be used instead. Wire lath is sold in rolls, and there are several advantages in running the lath in strips around the building, rather than putting on the length of the roll in a vertical direction. Expanded metal is generally sold in large sheets of various size, and may be cut up in such a manner as to make one sheet completely cover the space between two adjacent columns. It is generally advisable to put up a temporary wooden framing to hold the lath rigidly in position until the first plaster coat is applied.

Number and Thickness of Plaster Coats. Cement plaster is usually applied in three or more coats, designated as the first coat, the intermediate coat, and the finish coat. For best results no plaster coat should be more than half an inch thick, regardless of the thickness of the wall desired. In order to estimate the amount of cement and sand required in covering the walls with cement plaster, the following table has been prepared:

Table E

NUMBER OF SQUARE FEET OF WALL SURFACE COVERED PER SACK OF CEMENT, FOR DIFFERENT PROPORTIONS AND VARYING THICKNESS OF PLASTERING

Proportions of Mixture	MATERIALS			TOTAL THICKNESS OF PLASTER				
	Sacks Cement	Cu Ft. Sand	Bushels Hair*	½ In. Sq. Ft. Covered	¾ In. Sq. Ft. Covered	1 In. Sq. Ft. Covered	1¼ In. Sq. Ft. Covered	1½ In. Sq. Ft. Covered
1:1	1	1	⅛	33.0	22.0	16.5	13.2	11.0
1:1½	1	1½	⅛	42.0	28.0	21.0	16.8	14.0
1:2	1	2	⅛	50.4	33.6	25.2	20.1	16.8
1:2½	1	2½	⅛	59.4	39.6	29.7	23.7	19.8
1:3	1	3	⅛	67.8	45.2	33.9	27.1	21.6

*Used in scratch coat only.

NOTE—These figures are based on average conditions and may vary 10% in either direction, according to the quality of the sand used.

No allowance is made for waste.

After deciding upon the total thickness of the wall and the mixture to be used, it is easy to determine the total materials required for covering a given wall surface, since the table shows the number of square feet of surface covered by the mortar produced from one sack of cement. The table does not consider the cement mortar likely to be lost through waste when plastering; part of this waste, however, can be prevented

by placing a plank on the ground at the base of the wall to catch the plaster that falls. Plaster should never be used after it has once begun to harden and therefore should not be allowed to accumulate, but should be gathered up promptly and remixed with the mortar already prepared. It may be well to state here that cement plaster should not be mixed in batches larger than are needed for immediate use, otherwise, some of the mortar may begin to harden before it can be used and must therefore be thrown away.

When the sand used for the mortar is practically dry, the cement may be mixed with the dry sand in one sack batches and portions of this mixed with water as required. When the materials cannot be handled in this way and the mortar must be mixed in batches requiring less than a sack of cement, the proper amount of cement should be measured by weight and not by bulk. If it is kept in mind that one sack of cement contains one cubic foot and weighs 94 pounds, it is easy to determine the weight of any desired fraction of a cubic foot.

Mixtures for Mortar. For the first coat a mixture of 1 part cement to 2 parts clean, coarse, well graded sand is recommended to which 1/8 bushel of hair or fibre is added per barrel of cement. The hair or fibre should be soaked thoroughly and well separated before using it in the mortar; the best results will be obtained if the proportion of hair or fibre is mixed thoroughly with the required amount of dry sand before adding the cement.

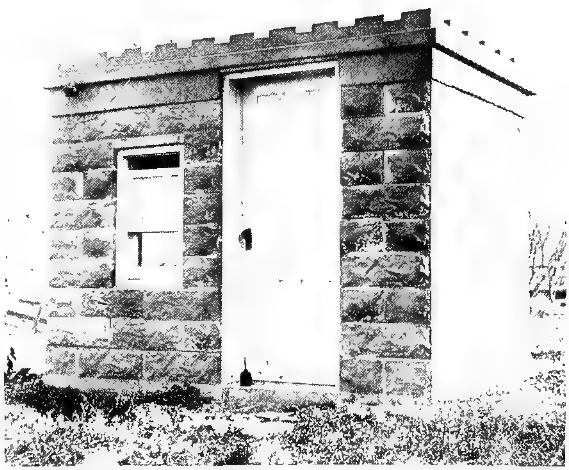


Figure 48. Concrete Block Well House of Mr. M. Sullivan, Marshall, Minnesota. Marshall Tile and Sidewalk Company, builders.

There is a tendency among plasterers to use lime in the first coat and sometimes in the other coats, but because of the danger of getting unslaked material into the mixture, the use of lime is to be discouraged. If lime is permitted it should be added in the proportions of one part lime putty to ten parts cement and sand mortar. At least two weeks before using it in the mortar, the lime should be slaked thoroughly; a day or two before beginning work the lime should be reduced to liquid form by the addition of water and should be strained through No. 16 sieve into a tight box to remove any unslaked particles. This mixture should then be allowed to settle and form a lime putty, the surplus water being drawn off or evaporated; the lime putty may be kept indefinitely if not allowed to become hard.

Applying the Plaster. The first coat should be of such a thickness as will cover the lath and fill the meshes, and as soon as sufficiently hardened it should be scratched at right angles and at 45 degrees to the horizontal with a scratcher to provide a surface for the next coat. The scratcher may be made as shown in Figure 49. It should not cut a sharp line in the plaster, but rather form grooves with ridges on the sides, thus making a rough surface to receive the next coat.

The second coat and all subsequent coats should be applied after the preceding coat has hardened, but preferably before it has had time to dry out. Each coat should be brought to a true plane and, excepting the finish coat, should be scratched in the same way as the first coat. Immediately before applying any coat, the preceding coat should be thoroughly drenched and then treated with a grout of neat cement mixed with water to the consistency of thick cream. This grout is applied with a calcimining brush and the plaster must be put on before the grout shows the least indication of drying. All intermediate coats should be mixed the same as the first coat, omitting the hair or fibre.

Pebble-Dash Finish. For the finish coat a mixture of 1 part cement and 2½ parts coarse sand is recommended and this should be prepared and applied in the manner described for the previous coats. To obtain a rough cast or pebble dash finish the mixture above mentioned is dashed against the wall from the hand or from a paddle or a swab of tightly bound, pliable twigs, and adhering to the wall forms a rough, hard surface. Sometimes a part of the sand is replaced by an equal amount of small pebbles or limestone passing a ¼ inch screen and free from dust. The mixture is taken up in the hand or

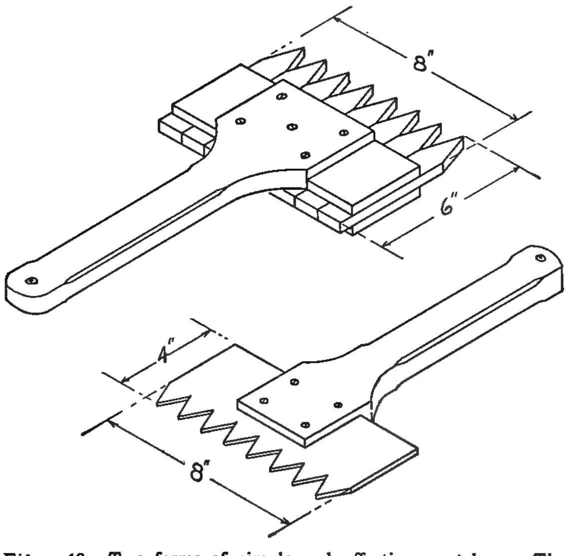


Figure 49. Two forms of simple and effective scratchers. The lower scratcher is made of an old saw-blade or scrap of tempered steel.

on the paddle or swab and thrown directly toward the wall; it should strike squarely, for if the mixture strikes the wall at an angle it will not adhere. After some practice, the material can evenly be distributed over the wall by this means. The texture of this finish will vary with the size of the material used in the mixture, and with the consistency, but in all cases the dust and fine particles should be removed from the aggregate. Before starting to apply a pebble-dash finish it is wise to experiment with small areas of surface made with various sized materials. This may be done in out-of-the-way places in the wall, and later covered, if necessary. In this manner an idea of the various texture is obtained, and an intelligent selection is made.

Precautionary Measures. In plastering buildings the work should be planned so that, if possible, an entire wall of the structure can be covered with plaster in one day; this will tend to produce uniformity in the texture and color. Great care should be taken to keep the materials, the proportions and consistency of the mixture, and the methods of application the same from day to day, for variation in one or all of these will produce a wall of mottled appearance. This is especially important for the finish coat, where it is highly desirable to produce a uniform color and surface. Should it become necessary to stop work before any coat has been applied to the entire surface, the treatment to obtain proper bond should not be ignored. No plastering should be done during freezing weather. In hot weather the plaster should be protected from sun or drying winds; otherwise cracking and checking from too rapid drying may result. Protection may be provided by hanging a cloth six inches or so away from the wall and keeping this damp until the paster has well hardened.

Figure 50. Concrete Block Corn Crib on the Farm of C. D. Babb, near Wagner, Illinois. Mr. Babb has two cribs of this type which have been in use for two years and are giving satisfaction.

Concrete Roofs for Farm Buildings

ON the average farm, with six to twelve buildings, the work of keeping the shingled roofs in repair frequently consumes much time and makes considerable expense, and at best some of the roofs are nearly always in a leaky condition.

Wooden roofs are short lived, need frequent repairs, often become warped and unsightly, and are liable to cause the destruction of the whole building by fire, even though other parts are built of practically non-combustible materials. The roof is the most vulnerable part of the building; it is exposed to sparks and embers from without, and if made of a combustible material, is easily set ablaze by fires from within, which quickly reach the roofs of small buildings. Steel roofs are expensive in first cost and upkeep, requiring frequent painting to prevent rusting out. Such roofs are easily blown off by high winds, and readily twist out of shape or collapse under the heat of a fire.

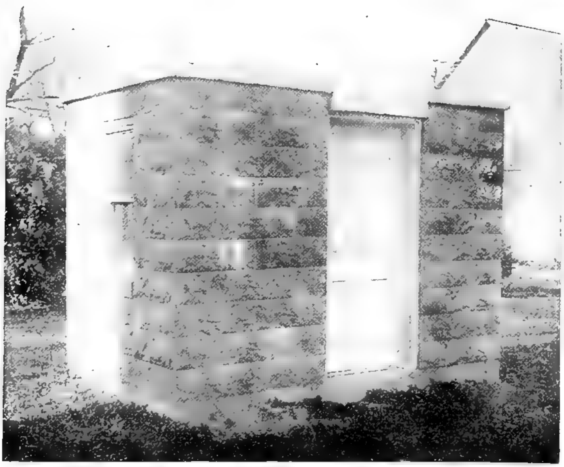


Figure 51. Concrete Block Well House with concrete roof. S. J. Forbes, Owner, Marshall, Minnesota. Built by the Marshall Tile and Sidewalk Company.

Although several roofing materials are available, concrete makes the best roof for small concrete farm buildings. The first cost of a concrete roof is very often no greater than that of a wooden roof, and when freedom from repairs is considered, the concrete roof is undoubtedly the cheaper. The extra expense of putting a concrete roof on a concrete building is not great, as the concreting materials for the roof can be hauled at the same time as those for the walls, and the additional work of mixing and placing the concrete amounts to only a few hours labor, with materials and tools already on hand. The forms need only consist of a floor of dressed boards rigidly supported by a scaffolding.

The ordinary types of wooden, steel and slate roofs require a comparatively steep slope to make them proof against driving rains. In contrast with these, the concrete roof may be made very flat—often having only one-quarter of an inch of rise per foot. If desired, the under side of the roof may be made perfectly flat, and the slope obtained by varying the thickness of the slab. The comparatively flat roof makes

a saving in materials by reducing the roof area. Concrete gutters may easily be formed on the eaves of concrete roofs, adding a desirable feature to the roof without the disadvantage of iron gutters, which rust out after a few years of service.

Types of Roofs Suitable for Small Farm Buildings. Flat roofs are the most simple to construct. They meet all of the requirements of small farm buildings, and at the same time are capable of high architectural development and may be built with less concrete and more simple form work than concrete roofs of other types. Gable roofs are a little more difficult to build than flat roofs, but where desired, these may successfully be constructed. Roofs having four sides sloping from a ridge or center may be successfully constructed if especial care is taken to get sufficient reinforcing metal correctly placed at the ridges. Such roofs have a tendency to crack at the corners unless adequately reinforced.

For buildings where the roof span does not exceed 8 feet, the unit beam and slab roof described on page 123, in connection with the hog shelter house, may be used. Such roofs have very few, if any, advantages over monolithic roofs, however, except that they may be removed, should occasion require.

Cement asbestos shingles put on wooden framing have been quite widely used during the last few years, and these make good, durable roofs. Cement asbestos shingles resist fire from without, but because of the wood rafters and sheeting, they are not proof against fire from within.

Flat Slab Roofs. Table F shows the thickness of slab required for concrete roofs of various dimensions from 4 feet square up to 16 feet square, and Table G gives the amount of cement, sand and stone (screened gravel or limestone) required for roofs of various sizes and thicknesses. Table H shows the size and spacing of reinforcing rods. To

Table F

THICKNESS OF ROOF SLABS IN INCHES.

Width in Feet Between Center Lines of Walls	LENGTH OF ROOF IN FEET BETWEEN CENTER LINES OF WALLS						
	4 Ft.	6 Ft.	8 Ft.	10 Ft.	12 Ft.	14 Ft.	16 Ft.
4 Ft.	2 In.	2 In.	2½ In.	2½ In.	2½ In.	2½ In.	2½ In.
6 Ft.		2½ In.	2½ In.	2½ In.	3 In.	3 In.	3 In.
8 Ft.			3 In.	3½ In.	3½ In.	3½ In.	4 In.
10 Ft.				3½ In.	4 In.	4½ In.	4½ In.
12 Ft.					4 In.	4½ In.	5 In.
14 Ft.						5 In.	5½ In.
16 Ft.							6 In.

Load = Weight of roof + 50 pounds per square foot.

find the thickness of slab, spacing of reinforcing rods, and amount of concreting materials and reinforcing metal necessary, proceed as in the example given at the bottom of this page.

TABLE G

Cement, Sand and Stone

Required for Concrete Slab Roofs. Proportions for concrete 1:2:3. Each cubic yard of 1:2:3 concrete requires about 1.74 Bbls. of cement, .52 cubic yards of sand and .77 cubic yards of stone.

			WIDTH OF SLAB IN FEET (BETWEEN EAVES)						
			4	6	8	10	12	14	16
Sacks of Cement (1 sack = 1 cu. ft.)	Length of Roof in feet between eaves	4	0.7	2.0					
		6	1.0						
		8	1.7	2.6	4.2				
		10	2.2	3.3	6.1	7.6			
		12	2.6	4.7	7.3	10.4	12.5		
		14	3.0	5.5	8.5	13.7	16.4	21.2	
		16	3.5	6.2	10.1	14.4	20.8	26.7	33.3
Cu. Ft. of Sand	Length of Roof in feet between eaves	4	1.4						
		6	2.1	3.9					
		8	3.4	5.2	8.3				
		10	4.3	6.5	12.1	15.2			
		12	5.2	9.4	14.6	20.8	25.0		
		14	6.1	10.9	17.0	27.3	32.8	42.5	
		16	6.9	12.5	20.2	28.8	41.6	53.4	66.6
Cu. Ft. of Stone	Length of Roof in feet between eaves	4	2.1						
		6	3.1	5.9					
		8	5.1	7.8	12.5				
		10	6.5	9.8	18.2	22.7			
		12	7.8	14.0	21.8	31.2	37.4		
		14	9.1	16.4	25.5	41.0	49.1	63.7	
		16	10.4	18.7	30.3	43.2	62.4	80.1	99.8

Example. Required, the thickness of slab, amount of concreting materials, spacing of lateral and transverse reinforcement, and the amount of reinforcing rods, for the flat slab roof of a building 12 feet by 14 feet in outside dimensions, with 12-inch eaves on all sides. The size of the roof slab between the center lines of walls will be 13 feet 6 inches by 11 feet 6 inches. Referring to Table F, we run down the vertical column at the left to the smaller dimension of the slab, which in this case is 11 feet 6 inches. As this dimension is not given in the table we take the next larger, which is 12 feet. Running across horizontally to the larger dimension of the slab (13 feet 6 inches) we find that this is not given in the table, but that we must take 14 feet. In the square

directly below 14 feet, and horizontally opposite 12 feet, we find the required thickness of the roof to be 4½ inches. By reference to Table G the quantities of materials required are easily obtained. The size of the roof over the eaves is 14 feet by 16 feet. The table is divided into three parts showing respectively the amounts of cement, sand and gravel required for roofs of various sizes. The upper portion of the table gives the number of sacks of cement required and those below it give the number of cubic feet of sand and gravel or stone necessary. By referring to the table we find that the roof will require about 25 sacks of cement, 53 cubic feet of sand and 79 cubic feet of gravel or stone.

Table H

SPACING OF REINFORCING RODS IN INCHES

Width in Feet Between Center Lines of Walls	LENGTH OF ROOF IN FEET BETWEEN CENTER LINES OF WALLS 4 Ft.	6 Ft.	8 Ft.	10 Ft.	12 Ft.	14 Ft.	16 Ft.	Size Steel
4 Ft.	12 In. 12 In.	9¼In. 24 In.	8 In. 36 In.	8 In. 36 In.	8 In. 36 In.	8 In. 36 In.	8 In. 36 In.	¼ In. Rd. Rods.
6 Ft.		6 In. 6 In.	4¾In. 12 In.	4 In. 36 In.	4 In. 36 In.	4 In. 36 In.	4 In. 36 In.	¼ In. Rd. Rods.
8 Ft.			11 In. 11 In.	9½In. 22 In.	9 In. 36 In.	7¾In. 36 In.	7¼In. 36 In.	⅜ In. Round Rods.
10 Ft.				8¾In. 8¾In.	7¾In. 16 In.	7 In. 27 In.	6½In. 36 In.	⅜ In. Round Rods.
12 Ft.					6½In. 6½In.	5¾In. 12 In.	5¼In. 16 In.	⅜ In. Round Rods.
14 Ft.						5¼In. 5¼In.	4½In. 8¾In.	⅜ In. Round Rods.
16 Ft.							4 In. 4 In.	⅜ In. Round Rods.

NOTE—Upper figures are for cross reinforcement; lower figures for long reinforcement

Load = Weight of roof + 50 pounds per square foot.

The spacing of the reinforcing rods is shown in Table H. As the roof is 11 feet 6 inches by 13 feet 6 inches between center lines of walls, the next larger dimension shown in the table should be used. These are 12 feet by 14 feet. By running down the left hand vertical column to 12 feet, then running across horizontally to the 14 foot column, we find that cross reinforcement (running parallel to the short sides of the house) should be 5¾ inches apart, and the longitudinal rods (running the long way of the house), 12 inches apart. Round or square ⅜-inch rods should be used as shown in the column to the right of the table. The roof being 16 feet long and 14 feet wide, over eaves, will require 34 ⅜-inch rods 14 feet long, parallel to the short sides and 17 ⅜-inch rods 16 feet long parallel to the long side.

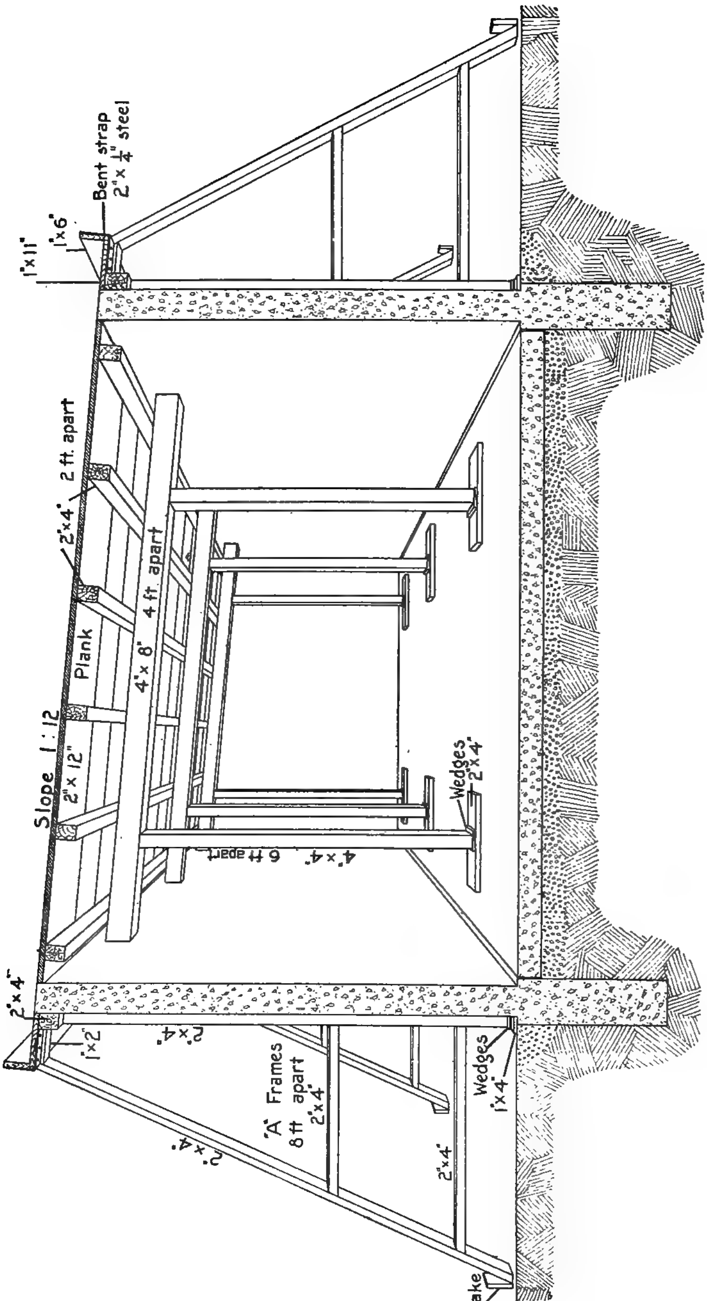


Figure 52. **Forms in position for concreting flat slab roof and eaves.**

Forms for Slab Roofs. A suitable method of constructing forms for flat slab roofs is shown in Figure 52. To insure a smooth ceiling the face of the planking next to the concrete should be dressed smoothly and tongued and grooved, although good results can be obtained with square edged lumber provided the edges are straight and in the same plane, so that no cracks will be formed between planks. Whitewash or crude petroleum oil applied to the surfaces of the lumber which will be in contact with concrete, is recommended, but if not used, these surfaces should be clean and wet at the time of concreting. Clay or putty may be used to smooth over small cracks or flaws.

Two-inch face lumber is recommended but lighter material may be used if sufficiently braced. Warped lumber should be avoided, although slight bows, lengthwise or crosswise will generally straighten out under the weight of the concrete. Lumber showing bowed edges should not be used unless the edges are redressed. All sizes shown in Figure 52 are stock sizes and readily obtainable. Forms can be erected without nailing or fastening except where specially directed and shown in the illustration; such fastenings should be avoided as they make the forms more difficult to remove and mar the timber for further use.

Erecting the Forms. In erecting forms the first step should be to divide the length of the floor beneath the roof by cross lines four feet apart. The posts to support the roof should be spaced six feet apart along these lines. These may be formed if desired by two 2 x 4's spiked together and may rest directly on the floor if the latter is of concrete or other firm material, but the better plan is to place short pieces of 8-inch plank under the ends of the posts. These also serve as a base for the wedges which are later to be placed under the ends of the posts to raise them to the proper level.

As the posts are raised, they can be braced lightly to the side walls and to each other. Posts on the same cross line are then connected at the top by 4 x 8-inch boards resting on edge, or two 2 x 8's nailed lightly together can be substituted by each 4 x 8. If these 2 x 8's are of proper length no stay bracing will be necessary. A light cleat nailed to the sides of the posts and the beams resting on them, will hold the bents together. The top of the beams should be about 6 inches below the top of the side walls, as the whole form will be trued up later by driving wedges under the bottom of the posts.

The stringers should be made of 2 x 4's two or three feet apart depending on whether one and one-half inch or two-inch face lumber is to be used. It is not necessary to spike these to the beams. On top of these are laid the face planks. The tops of the latter should be raised flush to the top of the side walls by driving wedges under the posts. These forms will support the concrete and the weight of the men during construction. Mixing boards or materials should not be placed on the roof forms, however, if any bending of the forms occurs after the placing of the concrete, nothing can be done to bring these back to their original place as any prying against them to line them up after they are covered will crack the concrete and spoil the work. If the directions given are strictly followed and the lumber is of good quality, no bending will occur.

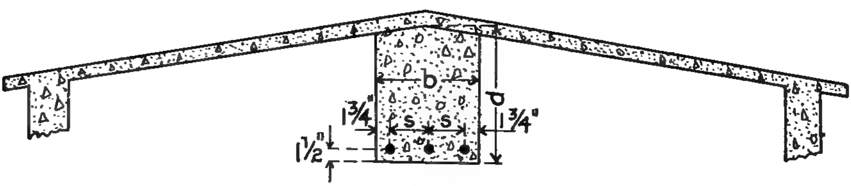
The forms should be left in place at least ten days in moderate weather or longer at lower temperatures but should not be taken down until all doubts have been removed as to whether or not the concrete can support the loads to be imposed upon it. In removing the forms the wedges may be knocked out between the posts and the bents carefully let down. The face planks, if not very carefully prepared, may give some trouble by sticking, and may have to be loosened by slight jarring from a temporary scaffold. Prying against the concrete should be avoided. If necessary, hooks or staples can be inserted in the bottoms of the planks to which ropes can be attached to pull them down.

Gable Roofs. (Size of Beam). Simple gable roofs for small concrete buildings need consist only of a ridge beam and two side slabs, of reinforced construction; or if the building is less than 8 feet in length, the ridge beam may be omitted. The following table gives the size of ridge beam and reinforcing required for roofs 8 feet to 16 feet in length between walls or supports:

Table I

SIZES OF RIDGE BEAMS FOR GABLE ROOFS

Length of Roof	8 Ft.		10 Ft.		12 Ft.		14 Ft.		16 Ft.	
Breadth of Beam (b)	6 In.		8 In.		9 In.		10 In.		10 In.	
Number of Rods	2		3		3		4		4	
Spacing of Rods	2½ In.		2¼ In.		2¾ In.		$2\frac{3}{16}$ In.		$2\frac{3}{16}$ In.	
Width of Roof	Depth of Beam	Size Rods	Depth of Beam	Size Rods	Depth of Beam	Size Rods	Depth of Beam	Size Rods	Depth of Beam	Size Rods
8 Ft.	9½ In.	½ In.	10½ In.	½ In.	12 In.	⅝ In.	13½ In.	⅝ In.	16 In.	⅝ In.
10 Ft.	10½ In.	½ In.	11½ In.	½ In.	13 In.	⅝ In.	15 In.	⅝ In.	17½ In.	⅝ In.
12 Ft.	10½ In.	½ In.	12½ In.	⅝ In.	14 In.	⅝ In.	16 In.	⅝ In.	18½ In.	⅝ In.
14 Ft.	10½ In.	½ In.	12½ In.	⅝ In.	15 In.	⅝ In.	17½ In.	⅝ In.	20½ In.	⅝ In.
16 Ft.	10½ In.	½ In.	12½ In.	⅝ In.	15½ In.	⅝ In.	17½ In.	⅝ In.	22 In.	¾ In.



The ridge beam may either be cast in place or in a mold box on the ground. The latter method insures proper curing of the beam before it is subjected to loads, but is objectionable because of the weight of the beam and the consequent trouble in raising it into place. If the beam is cast in position it can be made in a simple box mold supported on the same framing erected to carry the side slabs. Concrete should, in this case, be placed for beams and slabs at the same time, casting them together as a monolith.

Size of Slabs. To find the thickness of slab necessary for a gable roof from 8 feet square to 16 feet square (between supports) refer to

Table F on page 59. Thus, for the roof of a building 10 feet wide by 12 feet long, with the beam 12 feet in length (running the long way of the building) two slabs each 5 feet wide by 12 feet long (between supports) will be required. The above table gives the thickness of slab required, and Tables G and H give respectively the amount of concreting materials and reinforcing required.

Forms for the Eaves. The eaves can be formed by means of a mold made of three 2-inch boards joined by 2″ x ¼″ iron angle straps every five feet. Two of these boards should be wide enough to form the desired projection and the other wide enough to confine the concrete to the depth desired. The mold can be made of any convenient length, being fastened to the adjoining section after erection by light cleats.

The molds for the eaves may be secured in place in several ways. If the side walls are of monolithic construction and the forms still in place, steel or wooden brackets can be fastened to the studding for the support of the eave mold. In case this scheme is not available, the eave mold box can be supported at intervals of four or five feet by "A" frames, as shown in Figure 52. Unless waste lumber of some kind is available for use in the "A" frames, these need not be used if the mold box can be supported conveniently by the forms or staging.

Placing the Reinforcing. The required number of reinforcing rods, their size and spacing, having been obtained from Table H, these rods may be ordered from the local dealer or blacksmith. The spacing of the rods should be marked off on the forms, and the rods then laid down and wired together at all intersections. The reinforcing should then be placed upon small wooden or concrete blocks in such a manner that the rods will be imbedded about one inch above the bottom of the roof. It is very important that the rods should not come closer than one inch to the bottom surface of the roof; and, on the other hand, the effectiveness of the reinforcing is reduced greatly if they are placed any higher.

Reinforcing in Gable Roofs. The slab reinforcing rods running at right angles with the ridge should extend from eave to eave continuously, that is, not being broken off at the ridge. This binds the two sides of the roof together as one slab. The reinforcing should be brought out for the eaves in the same manner as for simple slab roofs.

Mixing and Placing the Concrete. It should be remembered that a concrete roof is intended to be a permanent roof, and that all work should be done in the best possible manner. There is often a tendency in the mixing and placing of concrete to be careless or "slipshod" but nothing short of the best workmanship and materials should go into the construction of the concrete roof.

Concrete for the roof should be mixed in the proportion of 1 sack of cement to 2 cubic feet of clean, coarse sand to 3 cubic feet of screened gravel or crushed stone. Great care should be taken to see that the sand and stone used are free from clay, loam, decayed rock, or other weak or injurious matter. It is not good practice to use bank run gravel; much better results can be obtained with a saving of cement by screening out all material less than ¼-inch in size to be used as sand, retaining the larger materials to be used as gravel proper. If bank run gravel

is used, the proportion should be no leaner than 1 sack of cement to 4 cubic feet of gravel. Where crushed stone is more easily obtained than sand and gravel, this material may be substituted, care being taken, however, to screen out all excessively fine particles and dust.

The concrete should be mixed thoroughly. Place the cement and sand (or other small aggregate) on the mixing board and turn together until the mass is uniform in color. Then add the large gravel or stone and add the water. Turn the mixture at least three times, after adding the stone, using additional water as required. The concrete should be mixed wet enough to be quaky, but not so wet that the water in the mass will flow to the lower side of the roof.

Where a comparatively flat concrete roof is to be put on a building with monolithic walls, the walls may be brought up to the proper height and squared off in the same manner as for a wooden roof, and no reinforcing rods need extend from the walls up into the roof. The concrete for the roof may be laid directly on the top surfaces of the walls without grouting. This leaves a break or parting between the roof and the walls, which allows the former to expand and contract freely with change of temperature.

If the roof is to have a pitch steeper than 2 inches to the foot, it is advisable to join it to the walls. This is necessary to prevent slipping or traveling of the roof. Where the walls and roof are to be joined together rigidly, the vertical reinforcing should protrude about a foot above the top of the walls. The top surface of the walls should be left rough, and should be drenched with water, and then painted with a grout immediately before the concrete for the roof is placed.

The same equipment used to convey and raise the concrete in the walls can generally be used for the roof. With the reinforcing metal placed in position, as previously mentioned, enough mortar should be placed on the floor of the forms to work under the reinforcing. The blocks used to hold the rods up off the forms may then be withdrawn, and the spaces occupied by them filled up. Concreting must not be stopped until the entire thickness of the roof, including the surfacing, has been put on. Small concrete slab roofs should be concreted entirely at one operation, that is, without stopping work at any time for more than twenty minutes. Larger roofs may be laid in sections, as mentioned on page 140, discontinuing and resuming of the work as directed there.

Finishing the Roof. The roof should be finished off in the same manner as a floor or a sidewalk, using for this work the tools shown in Figure 20. If the concrete, mixed in the proportion of 1 sack of cement to 2 cubic feet of sand to 3 cubic feet of small stone does not give a sufficiently smooth surface when trowelled, a small quantity of mortar may be added to the top. The roof need not be squared off into panels.

Protection Against Weather. One of the most important points in successfully constructing concrete roofs is to protect them from the time they are laid until they have hardened sufficiently, and acquired ample strength to withstand the action of sun, wind, rain and freezing. This may be done conveniently by covering the roof with wet straw, weighted down to keep it in place. The straw should be kept wet, and

not removed from the roof for at least two weeks. Precautions in this regard are necessary to insure against possible checks or cracks caused by premature exposure to sun or wind, and also prevent freezing, with consequent loss of strength.

Figure 53. Monolithic Ice House and Dairy of C. H. Zehnder, Allenhurst, N. J.

Figure 54. Concrete Block Cattle Shed on farm of N. Hampe, Rock Rapids, Iowa. Dimensions 30 feet by 40 feet. Cost, $300.

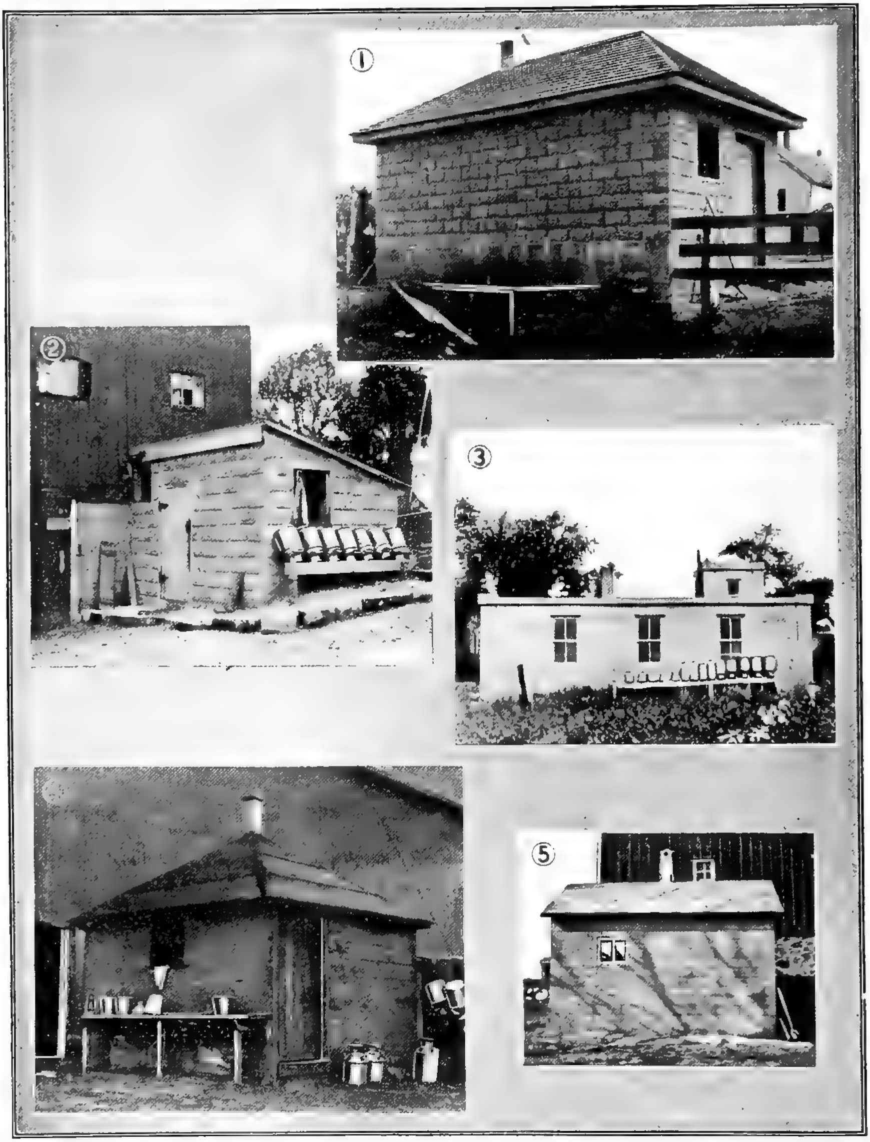


Figure 55. CONCRETE DAIRY HOUSES.

(1) J. M. Thalin, McHenry, Illinois. Built by owner.
(2) C. S. McNett, Cary, Illinois. Built by owner.
(3) Beech Farm Dairy, Coldwater, Michigan. R. C. Angevine, Contractor.
(4) Wm. Fareman, Burlington, Wisconsin. Built by owner.
(5) Merestead Farm. Built by owner.

PART II.

Dairy Buildings

THE dairy is the department of the farm where absolute cleanliness is demanded. The first great requirement of a dairy building is that it be scrupulously clean. There should be no decaying wood construction to serve as a breeding place for germs, and no cracks or crevices in the floor or walls to collect dirt and make proper cleaning difficult or impossible.

The rules and regulations of the New York Board of Health prescribes, among other things, that (1) Milk houses must be kept clean and used for no other purpose than the handling of milk. (2) They shall be provided with sufficient light and ventilation, with floors properly graded and watertight. (3) They shall be provided with adjustable sashes to furnish sufficient light, and some proper method of ventilation must be installed. (4) Milk houses should be provided with ample supply of clean water for cooling the milk, but if it is not a running supply the water should be changed twice daily. (5) Milk houses must be screened properly to exclude flies.

Figure 56. Concrete Block Milk House of Mrs. Godfrey Anderson, Elgin, Illinois.

The health officials of Chicago, as well as those of numerous other large centers of population, now require farmers shipping milk into the city to provide their milk houses with concrete floors, and the trend in all of the great dairying communities of the country is clearly toward all-concrete construction for such buildings. Beside the advantage of cleanliness, the concrete dairy house adds greatly to the general convenience of handling the milk and keeping it cool, and, when properly put up, constitutes the most permanent form of construction possible. It is free from the necessity of frequent painting and repairs, and this item alone is quite important. The difference in cost between wooden and concrete dairy buildings is insignificant in most cases, and several instances have been found where concrete was actually cheaper than wood.

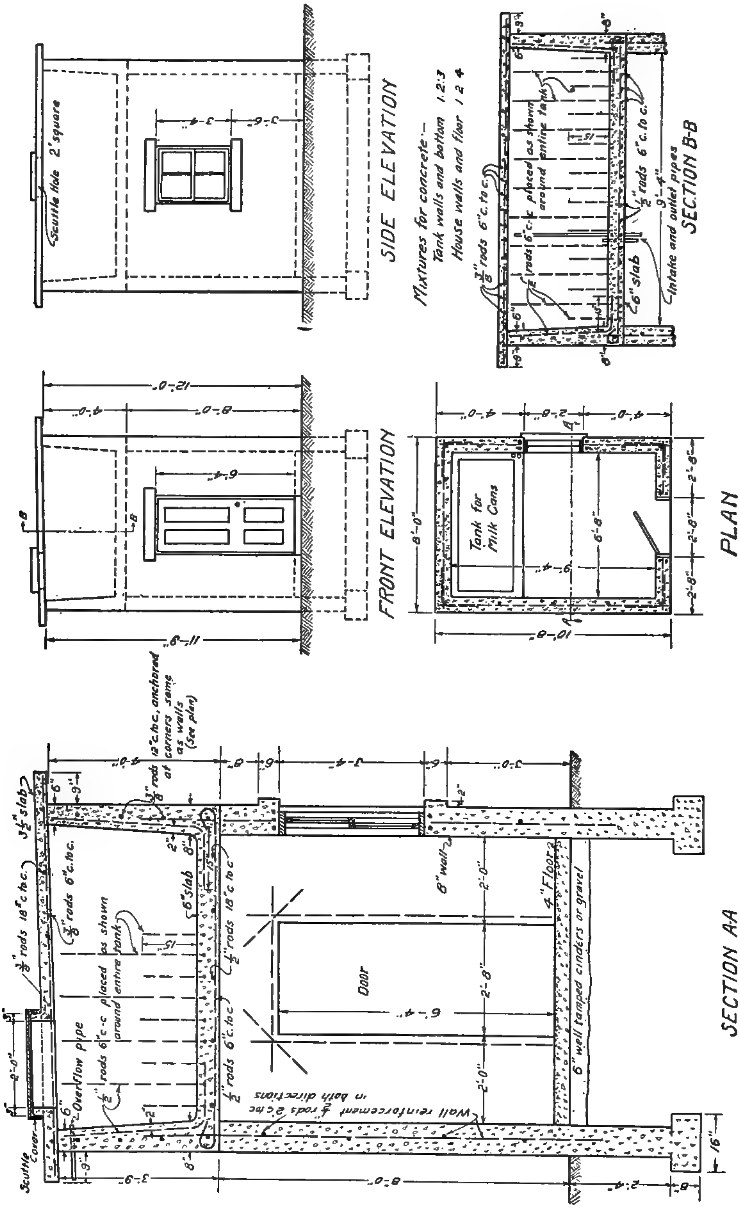


Figure 58. Reinforced Concrete Milk House with Overhead Water Supply Tank.

Location of Dairy Buildings. The milk house or other dairy building should be located conveniently with respect to the dairy barn. Dairy houses frequently adjoin the barn, or are built under an approach to the second floor. If this be done, the milk house must have no direct connection with the barn, and must be separated by a solid wall, without doors. Many authorities maintain that the milk house should be built entirely separate from the barn and at some distance; while not considered necessary in all cases, it is undoubtedly a good precautionary measure.

It is best to locate the milk house on elevated ground, and to comply with health department regulations in sections of the country subject to inspection, that no hog-pen, manure pile or other unsanitary object shall be closer than 100 feet. After considering the location with regard to the sanitary requirements, the site selected should be as near as convenient to the milking floor, so that the distance the milk has to be carried will be made as short as possible. In Circular No. 143 by the Illinois Experiment Station, Professor W. J. Fraser says:

"People do not stop to consider the amount of time that might be saved if a little more intelligence were exercised in tasks done two or three times each day. To illustrate this, take the matter of having the milk room inconveniently located. If the milker carries the milk of each cow 50 feet farther than need be, that means three rods and back each milking, or twelve rods per cow each day. If a man milks 12 cows it causes the extra labor of carrying a pail of milk 72 rods and carrying back the empty pail each day."

Figure 57. Concrete Block Milk House of Theodore Alby, Rochester, Wisconsin. J. A. Kilpatrick, Contractor. Dimensions, 12 feet by 10 feet. Cost, $125.

A location to the north of the barn is preferable, as it keeps off the warm rays of the sun. Where an approach to the second floor of the barn is to be built, there are a number of advantages in locating the dairy room under this approach. By so doing, the walls of the approach are made to serve a double purpose, the heavy roof over the dairy room keeps it cool, and the location is convenient.

A Reinforced Monolithic Milk House with Water Supply Tank

THE reinforced monolithic milk house shown in Figure 58, will be found well suited to the needs of the average small dairy farm. The building is 10 feet 8 inches by 8 feet in outside dimensions and slightly more than 12 feet in height from the ground line to the top of the roof.

It is provided with a water supply tank with a capacity of 23 barrels or 725 gallons, and a cooling tank of sufficient size to accommodate ten 14-inch milk cans. In case the owner has a more desirable location for the supply tank or for any reason he does not wish to place a supply tank on the structure, the roof may be built directly above the milk room, omitting the tank.

The foundation may be placed without forms if the ground is firm enough to stand up around the excavation, which should be 3 feet or more in depth and 12 to 16 inches in width. If the ground is of such a character that forms must be used, the type of foundation shown in the illustration will be the most economical to put in. In this case, the footing (16 inches wide and 8 inches in depth) may be put down without forms. The wall forms may then be placed directly upon the footing, continuing the foundation up to the surface with the same width as that of the wall above ground, or allowing it to bulge to the width of the footing by tilting the forms.

Figure 59. Monolithic Milk House of John Rhinehardt, Elgin, Illinois. The walls are marked off in imitation of concrete blocks. Dimensions, 10 feet square by 8 feet in height.

The work of building the walls and roof may be accomplished in accordance with the suggestions for such construction given in Part I. of this volume. The method of placing and the proper spacing of wall reinforcing around openings and at corners is shown in Figures 35, 36, 37 and 38. The door and window openings are made by placing temporary wooden frames within the forms at the proper positions. The sill and lintel projections around the opening may be formed by small box-like additions built or clamped into the wall forms as shown in the design of a Monolithic hog house, Figure 121, page 139. The vertical reinforcing should extend up about 20 inches above the bottom of the tank floor.

Forms for the floor of the supply tank may be put up as shown in Figure 52, or if preferred the tank floor forms can be supported upon the wall forms if the latter are built substantial enough to take the weight of the concrete placed in the tank floor as well as that of the forms. The

floor reinforcing should consist of ½-inch round or square rods spaced at intervals of 6 inches across the short dimension of the structure (shown in Section B-B Figure 58) and at intervals of 18 inches parallel to the long dimension of the structure (shown in section A-A Figure 58). The ends of these reinforcing rods should be brought around the wall reinforcing and bent back into the floor of the tank to develop maximum strength. The reinforcing should be placed an inch above the bottom of the floor, with ends bent back above the reinforcing, as shown.

After the forms for the floor are in place the reinforcing rods should be laid down and wired together. One inch of concrete (of a quaky consistency) should then be placed within the forms and the reinforcing raised up so as to rest on the one-inch layer of concrete. Before this concrete has had a chance to harden, three inches more concrete should be put down and leveled off, and the reinforcing for the wall of the tank then placed.

The tank wall reinforcing should consist of ½-inch rods bent in such a manner that 15 inches of their length will be imbedded in the floor. These rods are placed 6 inches apart, center to center, all around the tank, each alternate rod being 5 feet long so as to extend to the top of the tank wall, with the intermediate rods 32 inches long, which allows them to extend up about 15 inches above the floor slab. The reinforcing rods should be bent ready for use before the work is begun, and should be placed and wired as rapidly as possible so that concreting may be resumed immediately. Two inches of additional concrete will bring the floor slab to the required thickness, which is 6 inches.

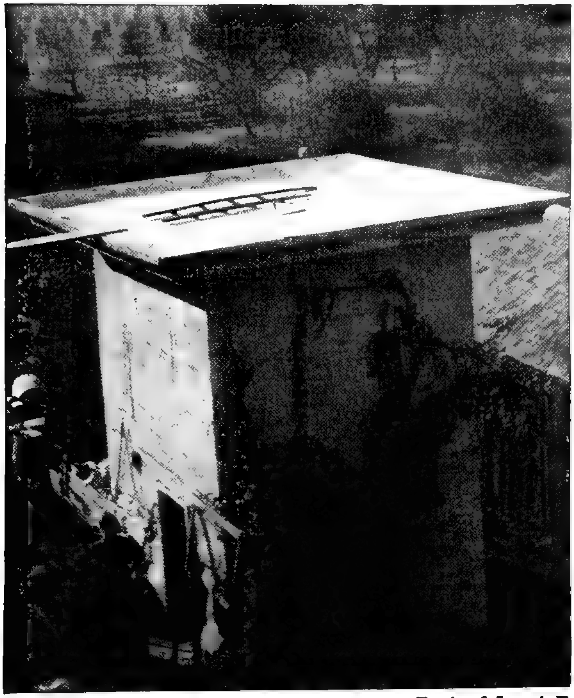


Figure 60. Concrete Dairy House and Water Tank of Joseph E. Wing, Mechanicsburg, Ohio, showing the flat slab concrete roof with ornamental cornice.

The outside wall form will serve as the outer form for the tank wall, and the inner wall form may be used as the inner form of the tank. In order to insure against damage from freezing, the inner walls of the tank must have a slight batter, making them 8 inches thick at the tank floor tapering to a thickness of 6 inches at the roof. If the inner walls

are made smooth and the work done as here directed, this batter should be sufficient to withstand any ice pressure which may come upon the tank. The forms used for building the floor of the tank may be used for the roof, provided a sufficient length of time has elapsed so that they may be safely removed. The forms should be allowed to remain in place until there are no doubts as to whether or not the floor has acquired sufficient strength to withstand the loads imposed upon it. Even under the most favorable circumstances the forms should remain in place five or six days, but under unfavorable conditions two weeks or longer may be required.

General directions for placing the reinforcing and building the eaves and other general operations about the roof will be found in the chapter on roofs, page 58. A scuttle hole 2 feet square should be left in the roof as shown in Figure 58. In putting up the roof forms and inner tank wall forms it must be remembered that these will have to be taken out through the scuttle hole. For this reason it would probably be advisable to use short lengths of lumber for this work as it may have to be damaged in removing from the tank. For this work only the use of lumber of uniform thickness is advisable.

The intake and outlet pipes for the water supply tank should be put up before the tank floor is concreted, drilling holes through the forms to accommodate the pipes. This method is the only satisfactory way of placing the pipes without danger of leaks.

Proportions (See page 157). Footings and foundation walls, Specification D. Wall from ground to bottom of tank, and tank roof, Specification C. Walls, roof, floor, and walls of tank, Specification A.

Figure 61. Concrete Block Milk House with ice room and water tank, on farm of M. D. Campbell, Coldwater, Michigan.

Table of Concreting Materials

	VOL. Cu. Yds	MIX-TURE	CEMENT Sacks	SAND Cu. Yds	SAND Cu. Ft.	STONE Cu. Yds.	STONE Cu. Ft.
Footings	1.15	1:3:5	5.3	0.06	16.2	0 99	26.7
Foundation Walls	2.00	1:3:5	9.3	1.04	28.1	1 72	46 4
Wall from Tank to Ground	6.22	1:2½:4	34.6	3.17	85 6	5.10	137.7
Floor	0 55	1:2:3	3.8	0.29	7.7	0 42	11 4
Tank Floor	1.15	1:2:3	7.6	0.60	16.2	0 88	23.8
Tank Walls	2 62	1:2:3	18.2	1.36	36.7	2.02	54.5
Roof	1 27	1:2:3	8.8	0 66	17.8	0 98	26 5
Total	....	....	87.6 (22 Bbls.)	7.72	208.3	12.11	327.0

Approximate amount of Reinforcing Metal required:

800 feet of ½-inch round rods................Weight 533 Lbs.
460 feet of ⅜-inch round rods................Weight 173 Lbs.

Total............................ 706 Lbs.

The table of concreting materials will be found accurate to within 10 per cent. In computing the amount of reinforcing metal no allowance was made for scrap or lapping, which will require about 10 per cent more material than the quantity stated.

Figure 62. A splendid monolithic concrete dairy house built by Edward Kuharske, on his farm near Rockford, Illinois. This building contains two commodious milk and separator rooms as well as a shelter for wagons. The shelter is on the north side of the house, and prevents the sun from reaching the south walls of the dairy rooms.

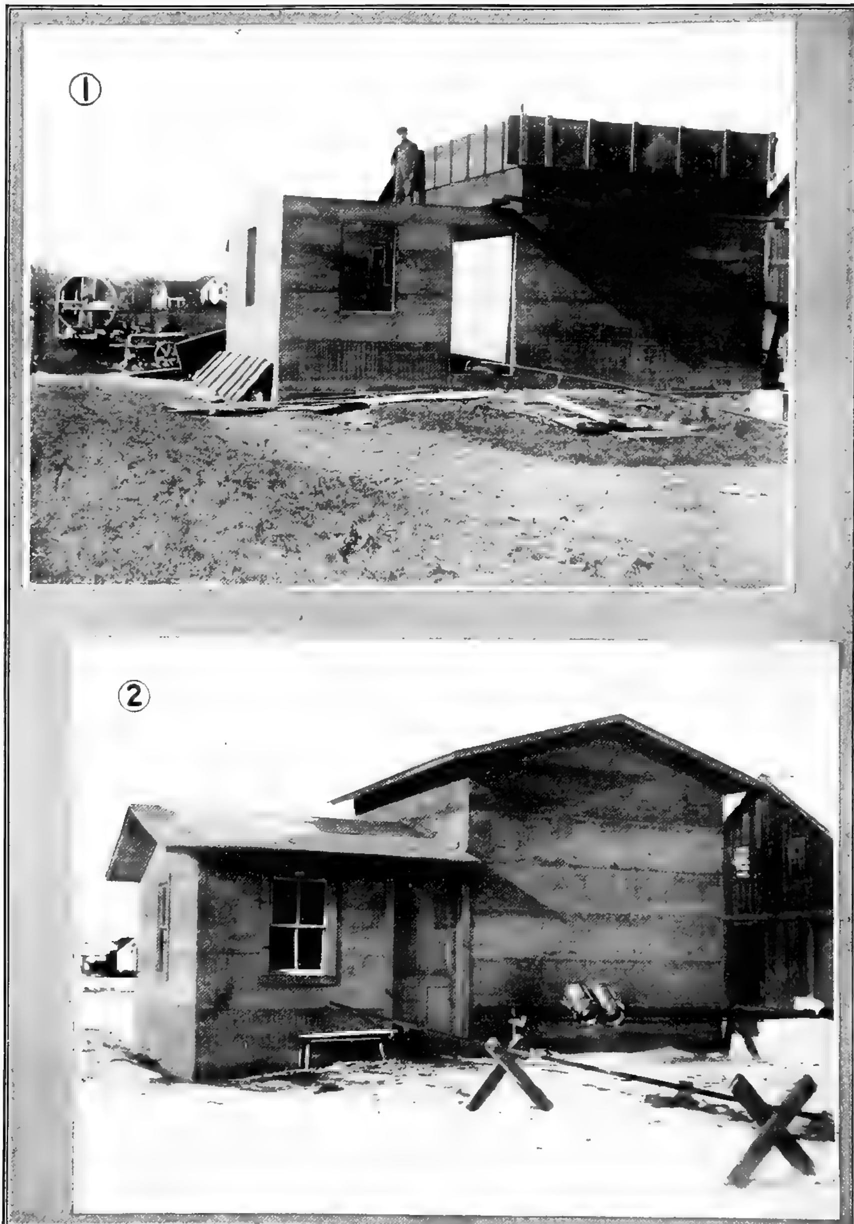


Figure 63. MONOLITHIC MILK AND ICE HOUSE.
Julius Clausing, Grafton, Wisconsin.

(1) Incomplete structure with forms on the walls of the ice room in position for last filling.
(2) Building completed. The walls are 6 inches thick. All the work was done by the owner.

Reinforced Concrete Milk House with Ice Room

AN ice room is often a great convenience in connection with the milk house, giving easy access to the ice for use in the cooling tank. Figure 65 shows a house with a large milk room and an ice storage room of ample capacity. The inside dimensions of the milk room are 9 feet 4 inches by 11 feet 8 inches, in which is located a cooling tank with space for 18 14-inch milk cans. The ice room is 10 feet square in inside dimensions, and has a height of 8 feet in the clear, giving it a capacity of 15 tons of ice. Allowing for shrinkage and waste, this should leave a sufficient quantity so that about 115 pounds per day will be available for four months.

The walls of the ice room should be made double, or a wall of veneer blocks may be constructed inside of a single monolithic wall, thus providing a free air space in either case. Double doors are provided for the ice room, and sawdust or some other good insulating material should be packed between doors. These doors should be lined with felt or other packing which will make them air-tight. The door to the ice room should be made in two or three sections so that in removing ice from the top only the first section need be opened, thus protecting the ice from an inrush of warm air. The milk room is provided with two doors, the one near the ice room door being used exclusively for bringing in the ice and the other door being used for the handling of the milk cans.

Figure 64. Concrete Block Milk and Ice House of J. A. Johnson, Libertyville, Illinois. The milk house is placed to the north of the barn, the shadows of which prevent the sun's rays from reaching the walls of the ice room except for a short time each day.

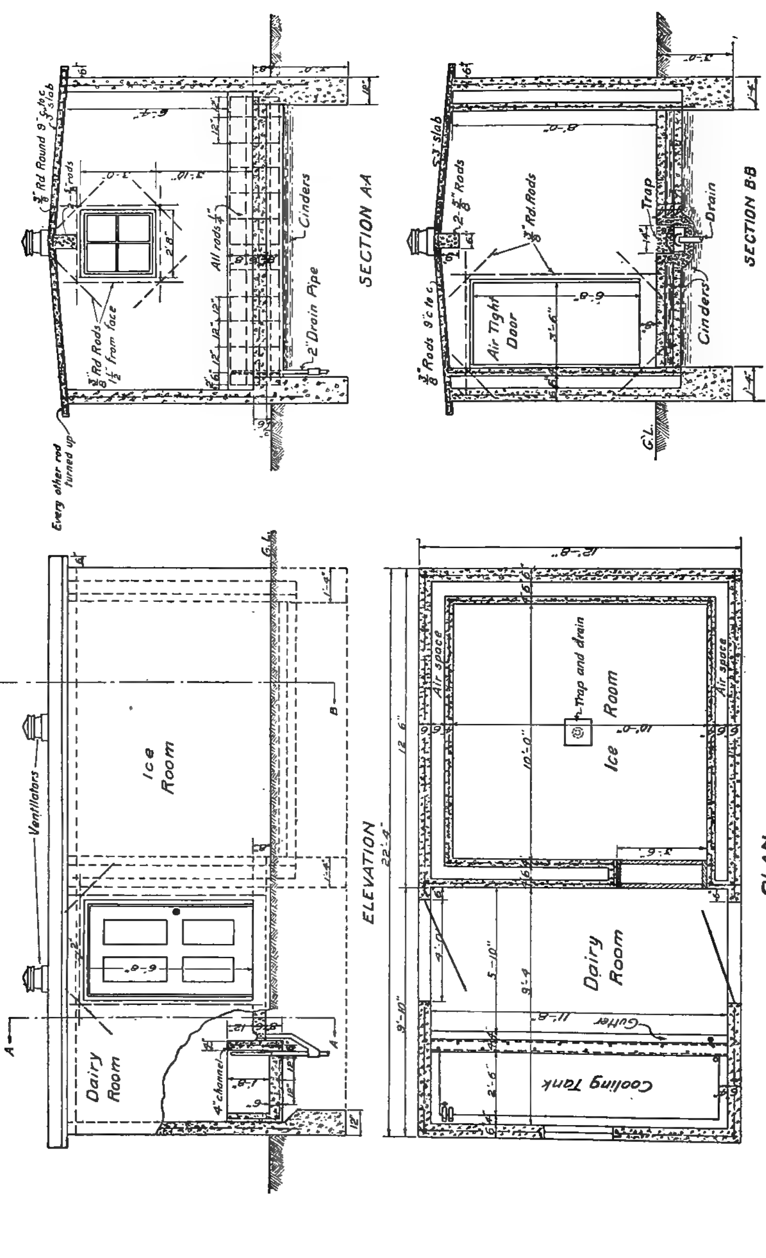


Figure 65. Reinforced Concrete Milk House with Ice Room.

Directions for building the monolithic walls, floors and roof will be found in Part 1 of this book. The ventilators provided in the roof are an important feature which should not be overlooked. Plenty of pure air is needed in the milk room to keep the milk pure and free from contamination. The ventilation in the ice room prevents the accumulation of warm air above the ice.

For best results, the floor of the ice room should be double with a layer of cinders or other insulating material between. The space between foundations should be excavated until a depth of about 16 inches is reached. Four inches of gravel should then be put down as a subbase for the floor and leveled off. A four-inch floor should next be put down and leveled off without giving it any surface finish. After placing 4 inches of cinders on top of this floor another slab similar to the first should be laid upon the cinders. As a precaution against possible cracking, the upper slab should be reinforced with a light fabric. Style No. 29, American Steel & Wire Company's Triangle Mesh, or some similar material, is suitable for this purpose. About two inches of concrete for the floor should be placed and leveled off, and the metal fabric then laid down. Concreting should immediately be resumed to insure a good bond between the concrete below and above the fabric.

The surface of the floor will not require a mortar top, but should be troweled off with a wooden trowel, using a small amount of mortar if necessary to make the surface sufficiently smooth. The surface should be given a slight slope—not over ⅛-inch to the foot—toward a central drain. Details of a suitable drain outlet are described on page 94, and shown in Figure 76, in connection with the concrete block ice house design. The milk room tank and floor should be put in the same as those previously described.

Proportions (See page 157).
Foundation, Specification D.
Floors, roof slab and cooling tank, Specification A.
Walls, Specification C.
Roof beam, Specification B.

Table of Materials

	VOL. Cu.Yds	MIXTURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Foundation	9.63	1:3:5	44.7	5.00	135.2	8.28	223.6
Ice Room Floor	2.48	1:2:3	17.3	1.29	34.8	1.91	51.6
Dairy Room Floor	1.33	1:2:3	9.3	0.69	18.7	1.02	27.7
Walls	12.52	1:2½:4	69.6	6.39	172.4	10.27	277.2
Roof Beam	0.30	1:2:4	1.8	0.14	3.7	0.27	7.2
Roof Slab	3.03	1:2:3	21.1	1.58	42.5	2.33	63.0
Cooling Tank	1.26	1:2:3	8.8	0.65	17.7	0.97	26.2
Total	.....	......	172.6 (43¼ Bbls.)	15.74	425.0	25.05	676.5

Reinforcing Metal required:

775 feet of ⅜-inch round rods................Weight 290 Lbs.
150 feet of ¼-inch round rods................Weight 25 Lbs.

Total.............................. 315 Lbs.

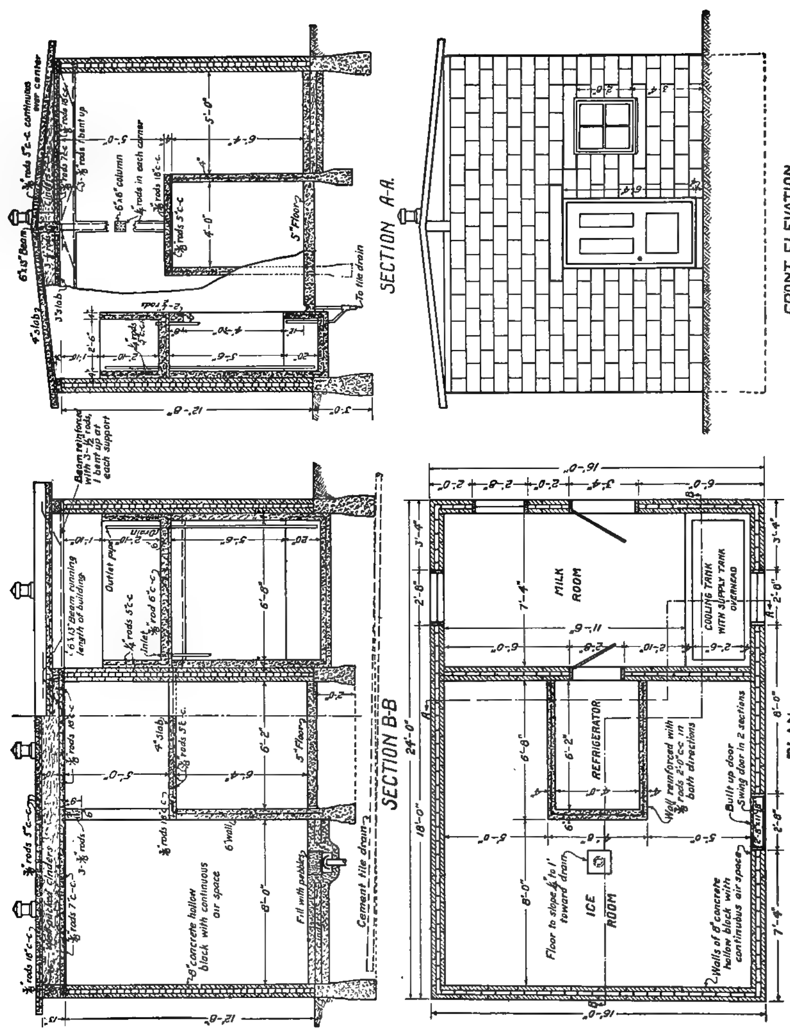


Figure 66. Concrete Block Dairy House with Ice Storage and Cold Room.

Concrete Block Dairy House with Cold Room

A DESIGN and detail for a concrete block dairy and ice house of moderate size is shown in Figure 66. The diary room contains two tanks, one directly above the other. The elevated tank receives the water direct from the well and overflows through the outlet pipe into the milk cooling tank directly below. The dairy room has a clear space 11 feet 4 inches by 7 feet 4 inches, making plenty of room for the separator, butter worker and work table. Three windows 2 feet 8 inches wide by 2 feet 8 inches long admit ample light.

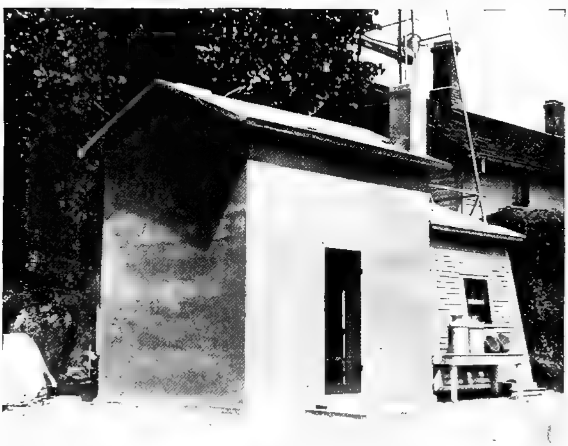
The refrigerator or cooling compartment opens off the dairy room and is surrounded by the ice room. This compartment is 6 feet long by 5 feet 4 inches wide and 6 feet high, giving plenty of room for the storage of milk, butter, cheese, eggs and other farm products. The design of the ice room and cooling compartment has been worked out with the idea of obtaining the maximum cooling surface with the expenditure of the smallest amount of ice. This has been accomplished by placing the cooling compartment within the ice room so that four sides of the former will be surrounded by ice. As the ice melts around the walls of the cooling compartment more ice can be packed in close to the wall to take the place of that melted. This arrangement of the cooling compartment partially overcomes the necessity of carrying ice into the dairy room.

Figure 67. Monolithic Milk House of Charles S. McNett, Cary, Ill. One of a dozen concrete structures on Mr. McNett's Farm.

The foundations for this building should be put in as directed in a previous section. The walls of the building are to be made of concrete blocks, the design being worked out for standard size (8x8x16-inch block) to be laid up as directed on page 46. The partition wall between the ice house and the dairy room should also be made of concrete blocks. The cooling compartment should be made monolithic rather than of hollow blocks as the monolithic wall makes a much better conductor of heat and cold than the block wall. The walls of the cooling room should be reinforced according to the directions given on pages 39 to 44 as shown in Figures 35 to 38.

The roof of the cooling or refrigerator compartment should consist of a flat slab 4 inches thick cast in position and reinforced with 3/8-inch round rods spaced 5 inches apart, crosswise of the compartment, and 18 inches apart in the other direction. A 6 x 6-inch column to support the roof beam above must rest upon the slab as shown and the column reinforcing, consisting of four 1/4-inch rods, should be imbedded in a slab at the time of concreting. The column should next be put in, using a common box mold similar to that shown in the root cellar design Figure 131. The reinforcing rods should extend up about a foot above the top of the column, so that they may be anchored into the beam above.

The roof of the house is of double construction made of a level and a pitched monolithic section supported on the walls of the building, the partitions between the milk room and the ice room, and a concrete beam 6 inches in width and 9 inches in depth across the ice room wall parallel to the partition. A concrete ridge beam 6 inches in width and 13 inches deep supports the upper slab and gives it the desired pitch. After the walls of the building are run up to the desired height the forms should be placed in position for the 6x9 roof beam, the flat section of the roof, the ridge beam and the end partition between the level and the pitched sections of the roof. The level roof slab should be made 3 inches thick and reinforced with 3/8-inch round rods 7 inches apart, center to center, the long way of the structure and 18 inches apart, center to center, the short way of the structure, placed one inch above the bottom of the slab. The beam below the slab should be reinforced with three 3/8-inch round rods placed as shown in sections A-A and B-B, Figure 66. The ridge beam should be reinforced with three 1/2-inch rods as shown.



Monolithic Milk House and Water Tank on top. M. G. Clark, Owner, Coldwater, Michigan. R. C. Angevine, Contractor.

The level section of the roof, the 6″ x 9″ beam below it, the end partitions between the level and the pitched sections, and the ridge beam are then concreted. The roof beam mold should be removed as soon as possible without injury to the beam. The forms supporting the roof slab and the beam below it should not be removed immediately however, but left in position until after the top roof slab has been concreted and all parts of the roof have acquired strength enough to support the loads imposed upon them. The upper roof slab should be concreted as soon as the level slab has been completed and the spaces between the level and pitched sections are filled up with cinders or some other

insulating material. For general information on the subject of roofs see pages 58 to 67.

The door opening between the milk room and the cooling compartment is 3 feet wide x 6 feet high and should be built with double walls forming a space which may be filled with shavings, sawdust, ground cork or some other good insulator if desired. The door opening into the dairy room from the outside is 4 feet wide and 6 feet 8 inches high. The ice room door is 2 feet 8 inches wide and extends the entire height of the building. It is built in several sections so that it is not necessary to open up the whole doorway thus exposing the ice to the warm air from without.

Figure 68. **An Extensive All-Concrete Dairy Plant on the Gedney Farms, White Plains, New York.**

The lintels and window sills may be cast in a home made mold similar to that shown in Figure 40, page 45, or may be purchased from a local concrete block manufacturer. The cooling tank in the milk room should be constructed in accordance with directions given on page 88 and the concrete floors laid.

Table of Concreting Materials

	VOL. Cu Yds	MIX-TURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Foundation	6.65	1:3:5	30.9	3.46	93.4	5.72	154.4
Floor	2.03	1:2:3	14.1	1.06	28.5	1.56	42.2
Walls (block) Body		1:2½:4	90.6	8.33	224.8	13.32	359.6
Walls Facing		1:2	19.1	1.41	38.2		
Walls of cold Room	1.92	1:2½:4	10.7	.98	26.4	1.57	42.5
Roof of cold Room	.82	1:2:3	5.7	.43	11.5	.63	17.1
Roof Beams	1.63	1:2:4	9.9	.73	19 8	1.45	39.2
Roof Slabs	9.00	1:2:3	62.6	4.68	126.4	6.93	187.1
Supply Tank	3.10	1:2:3	21.6	1.62	43.8	2.39	64.8
Sills	.62	1:2:3	4.3	.32	8.7	.48	12.9
Total	....	......	269.5 (67½ Bbls.)	23.02	621.3	34.05	919.8

The outside walls of the building require 931 standard 8″ x 8″ x 16″ concrete blocks, and the partition between the milk and ice rooms 179 blocks. If these blocks are purchased from a block manufacturer the quantities of materials given for the blocks should be deducted from the total. One cubic yard of 1:2 cement and sand mortar will be required in laying up the blocks. This mortar will require about 13 sacks of cement and 26 cubic feet of sand. Total amount of materials necessary, including amount required for manufacture of blocks and for mortar, 71 bbls. cement, 24 cubic yards of sand, 38 cubic yards of stone. If the blocks are purchased from a block manufacturer, 40 bbls. of cement, 13¼ cubic yards of sand and 24¾ cubic yards of stone will be required.

Approximate amount of Reinforcing Metal required:

3900 feet ¼-inch round rods	Weight	830 Lbs.
290 feet ½-inch round rods	Weight	250 Lbs.
160 feet ⅜-inch round rods	Weight	45 Lbs.
Total		1125 Lbs.

Proportions (See page 157). Foundations, Specification D. Concrete Block backing and walls, Specification C. Supply tank, sills and lintels, floor and roof, Specification A.

Roof beams, Specification B.

Small Reinforced Concrete Milk House with Loading Platform

WHERE it is convenient to have a platform from which to load or unload milk cans the design shown in Figure 69, will give satisfaction. The milk house is 10 feet 8 inches by 8 feet 8 inches inside dimensions. Should it be desired, the walls may be conveniently built of concrete block, as the standard size (8″x 8″x 16″) concrete block will conform nicely to these dimensions. The platform is on the side of the house opposite the cooling tank and double doors are here provided. The door for ordinary use is at the end of the house and is reached by four concrete steps. The tank will accommodate fourteen 14-inch milk cans, being 2 feet 6 inches in width, and 9 feet in length. If concrete blocks 8 inches thick are used, the inside dimensions of the building as well as those of the tank will be changed somewhat to conform.

The foundation and walls may be built in accordance with the suggestions previously given for such work. The loading platform should

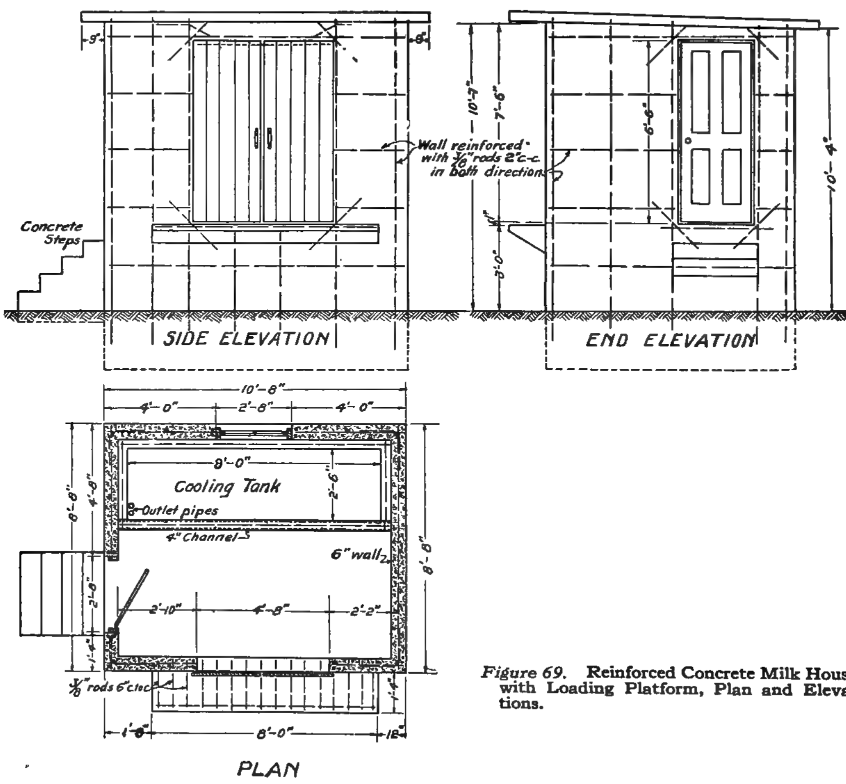


Figure 69. **Reinforced Concrete Milk House with Loading Platform, Plan and Elevations.**

extend out about 16 inches beyond the outside of the wall, and should be about 8 inches thick where it joins the wall, tapering to a thickness of 3 inches at the outer edge. The forms for the platform may be constructed easily of planks and hardly need detailed explanation. The reinforcing for the platform should consist of twelve ⅜-inch rods placed 6 inches apart, center to center, at right angles with the direction of the wall and three ⅜-inch rods parallel to the wall, placed as shown in the section diagram Figure 70, one rod being placed close to the edge of the platform and the other two in the wall as shown. The rods for the reinforcing at right angles with the wall should be 30 inches in length, so that they may be imbedded in the wall about 10 inches below the level of the platform. They should be brought up around the inside horizontal wall reinforcing rod, and then bent down to a horizontal position so as to extend to the edge of the platform. The horizontal portion of these rods should be placed an inch below the surface of the platform. If placed at a greater depth, the efficiency of the reinforcing will be decreased.

As a precaution against possible settling, the tank should rest on a concrete foundation. For this purpose lean concrete (Specification E, page 157), will suffice. This foundation should be high enough to bring the tank to the desired level, as indicated by the dimensions in the drawing.

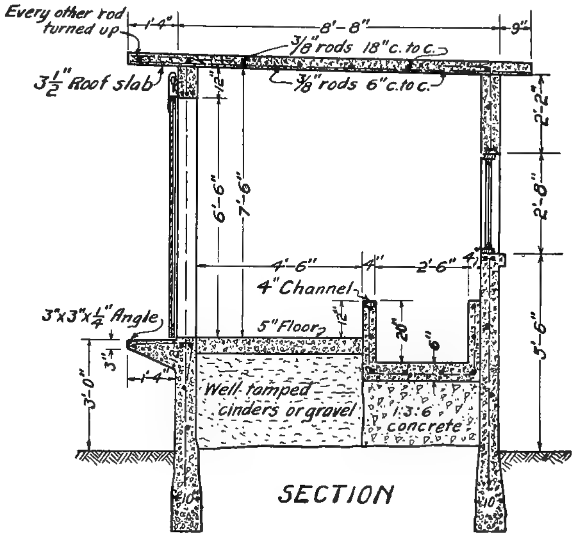


Figure 70. Reinforced Concrete Milk House with Loading Platform—Sectional View.

The tank and floor should be constructed separately, after the walls are completed. Care should be taken before laying the floor to have the

Table of Concreting Materials

	CONCRETE		CEMENT	SAND		STONE	
	Cu.Yds	Mixture	Sacks	Cu.Yds.	Cu.Ft.	Cu.Yds.	Cu.Ft.
Foundation	2.04	1:3:5	9.5	1.06	28.6	1.75	47.4
Floor and Platform	1.00	1:2:3	7.0	0.52	14.0	0.77	20.8
Walls	5.45	1:2½:4	30.3	2.78	75.1	4.47	120.7
Tank	0.97	1:2:3	6.6	0.50	13.6	0.75	20.2
Steps	0.30	1:3:5 1:2	1.7	0.16	4.6	0.22	5.9
Roof	3.00	1:2:3	20.9	1.56	42.1	2.31	62.4
Total	.....	......	76.0 (19 Bbls.)	6.58	178.0	10.27	277.4

Approximate amount of Reinforcing required:
400 pounds of ⅜-inch round rod.
(Order about 10 per cent extra to allow for waste in cutting.)

cinder or gravel fill beneath it well compacted, and a small amount of water may be used, if necessary, to aid this operation.

Full directions for building the concrete roof will be found on pages 58 to 67.

Proportions (See page 157).

Foundation, body steps, Specification D.

Walls, Specification B.

Tank floor and walls, roof, floor and platform, Specification **A.**

Surface coat for steps, 1:2 cement and sand mortar.

Concrete Block Milk House

THE concrete block milk house, shown in Figure 72, is designed to meet the conditions where a small house is desired, equipped with cooling tank, but without water supply tank or ice room. This structure is 10 feet 8 inches by 8 feet 8 inches in outside dimensions, and is made of standard 8 x 8 x 16-inch concrete block. The cooling tank is 2 feet 6 inches by 8 feet 8 inches in inside dimensions, and has a capacity of fourteen 14-inch cans.

The roof shown has a wooden frame, although a concrete roof built as directed on pages 58 to 67 would be preferable, the wood roof only being shown to illustrate the method of plastering the walls and ceiling. The wooden roof frame is covered with cement shingles or ready roofing, the former being superior to the latter because of their permanence and fire-resisting properties.

The inside walls of the building should be finished up smooth, preferably plastered. Metallic lath should be attached to the under side of the roof and the ceiling plastered up. The surface of the plaster should be made smooth, and all corners round, so that it may easily be

Figure 71. Dairy House of Wm. Stoll, Lansing, Michigan. Built of home made blocks made in a mold of Mr. Stoll's own manufacture.

washed down and kept free from accumulating dirt. The cement plaster for use in interior work should consist of one part cement, 1½ or 2 parts sand, with a possible addition of a small amount of thoroughly slacked lime, which will make the plaster easier to put on. The amount of lime added to the plaster should not exceed 5% of the whole. (See general directions on page 52). Directions for casting the window sills will be found on page 45.

Proportions (See page 157).

Footings, Specification D.

Concrete block backing, Specification C.

Tank floors and walls, sides and lintels, floor and platform, Specification A.

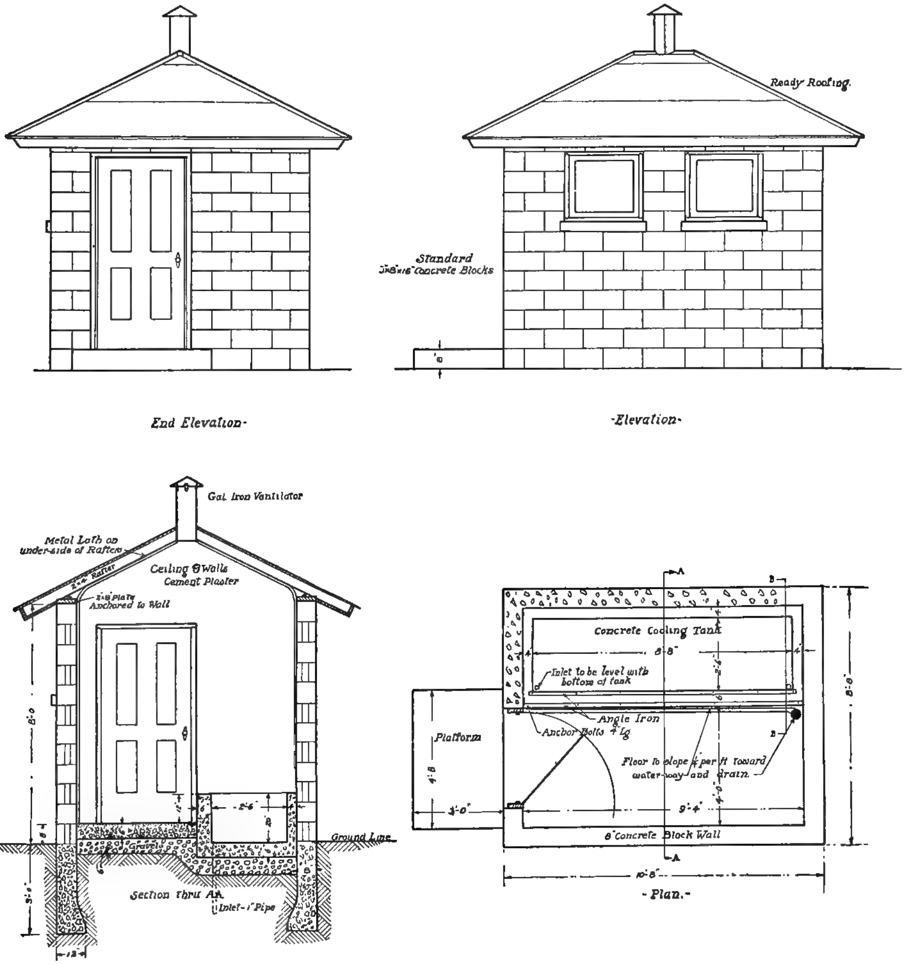


Figure 72. **Small Concrete Block Milk House.**

Table of Concreting Materials

	Cu. Yds. of Concrete	MIXTURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Footings	3.3	1:3:5	1.5	0.17	4.6	0.28	7.7
Walls (Block)*	270 Blks.	1:2½:4	22.0	2.03	54.7	3.24	87.5
		1:2	4.6	0.35	9.3		
Mortar	1.00	1:2	13.0	0.95	25.7	.....	......
Sills	0.06	1:2:3	0.4	0.03	0.8	0.05	1.3
Platform	0.34	1:2:3	2.4	0.18	4.8	0.26	7.1
Floor	0.70	1:2:3	4.9	0.36	9.8	0.54	14.6
Tank	1.15	1:2:3	8.0	0.60	16.2	0.88	24.0
Total	....	......	56.8 (14¼ Bbls.)	4.67	125.9	5.25	142.2

*Body of Block 1:2½:4.
Facing 1:2 cement and sand mortar.

Steel required for Tank:

24	¼-inch round rods 2 feet 2 inches long	52 Linear Feet
17	¼-inch round rods 3 feet long	51 Linear Feet
11	¼-inch round rods 9 feet 4 inches long	103 Linear Feet
	Total	206 Linear Feet

Weight 35 Pounds

(A few feet additional should be ordered to allow for waste in cutting.)

Design for Standard Milk Cooling Tank

THE accompanying illustration shows a standard design for a milk cooling tank. It will be found convenient to construct all cooling tanks wide enough to accommodate two rows of cans. Where the standard 14-inch cans are used, this width should be about 2 feet 6 inches. The desired capacity is obtained by varying the length of the tank.

The design shown in Figure 73 possesses a number of advantages. The tank is arranged at a distance below the floor which allows the operator to lift the cans with ease by obtaining a maximum purchase at the point where the cans are hardest to raise—just as they are leaving the water. It is recommended that the floor of the tank be 8 inches below the floor of the milk room, and that the tank be made 20 inches in depth inside. The standard size milk cans, when resting on the bottom of the tank, will then be surrounded by water up to the neck of the cans, and the possibility of the water entering the cans will still be precluded.

The tank floor and walls should be concreted at one operation. The floor of the tank should be 6 inches thick and the walls 4 inches thick. Reinforcement should consist of ¼-inch round rods spaced as shown in the illustration. Ten longitudinal rods are required, these

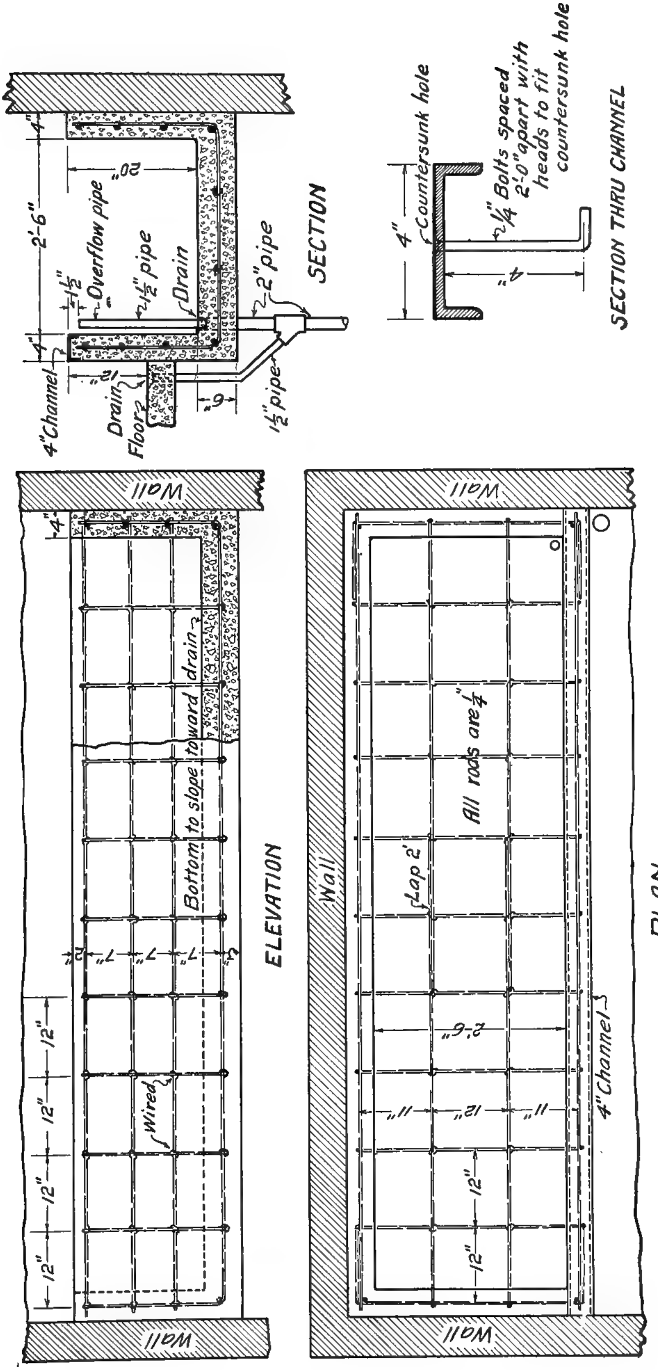


Figure 73. **Plan of Standard Milk Cooling Tank.**

being spaced 7 inches apart in the walls, and 11 or 12 inches apart in the floor. The crosswise reinforcing rods (which are bent up into a "U" shape as shown in the section) are spaced 12 inches apart. The longitudinal rods in the walls should extend around the tank as bands, care being taken to lap the ends of these rods for a distance of 24 inches. The reinforcing should be securely wired together at all intersections.

Concrete for the tank should be mixed in the proportion of 1 sack of cement, to 2 cubic feet of sand, to 3 cubic feet of screen gravel or stone, (Specification A, page 157), mixed with enough water to give it a "quaky" consistency. The top of the tank wall, over which the milk cans must be lifted, should be reinforced with a piece of 4-inch channel iron, anchored in the concrete by ¼-inch bolts with heads counter-sunk in the channel, as shown in the section through channel. These bolts should be spaced about 2 feet apart.

Care should be taken before concreting to see that a firm base is provided. If the ground below the tank has been disturbed recently, or, if for any other reason, it is not firm, it should be packed down with the use of water, if necessary, and a 6-inch fill of cinders or gravel put in. Negligence in securing a good foundation for the tank occasionally causes trouble, as the settling of the ground beneath any portion of the tank will subject it to heavy strains.

Figure 74. Concrete Block Ice House on the farm of Mrs. Gallup, Rochester, Wisconsin. Built by J. A. Kilpatrick, Rochester. Size 14 feet square by 16 feet in height. Capacity, 90 tons. Cost, $325. The ice is kept with minimum shrinkage, and the house will never warp out of shape.

Concrete Ice Houses

THE farm ice house is coming to be considered more of a necessity than a luxury. During the heat of the summer the souring of milk and the running of butter are not only an inconvenience, but in many cases mean the loss of considerable profit. Where ice is easily obtainable from lake or stream, the ice house is generally a saver of money on the dairy farm, not to mention the added convenience.

The first essential of a good ice house is insulation against heat. To insure this the walls and the floor and even the roof of the ice house are built so as to include one or more layers of an insulating material, and ventilators are provided in the roof to prevent the accumulation of warm air underneath. Mineral wool, charcoal, cork, felt, paper, sawdust, cinders and air which is confined, are the more common insulators. Insulating materials are always much more effective when dry than when wet, and for this reason it is important that the house be constructed of materials which will not allow moisture from the melting ice to reach the insulating material.

A wooden ice house is usually an unsightly structure after it has been up for a short time. It is generally warped and out of shape, and the sills and lower timbers decay rapidly from the dampness caused by the melting of the ice. Steel rods or struts used to brace such buildings make good conductors of heat from the outside with a resulting loss of ice through shrinkage. Insurance companies consider wooden ice houses

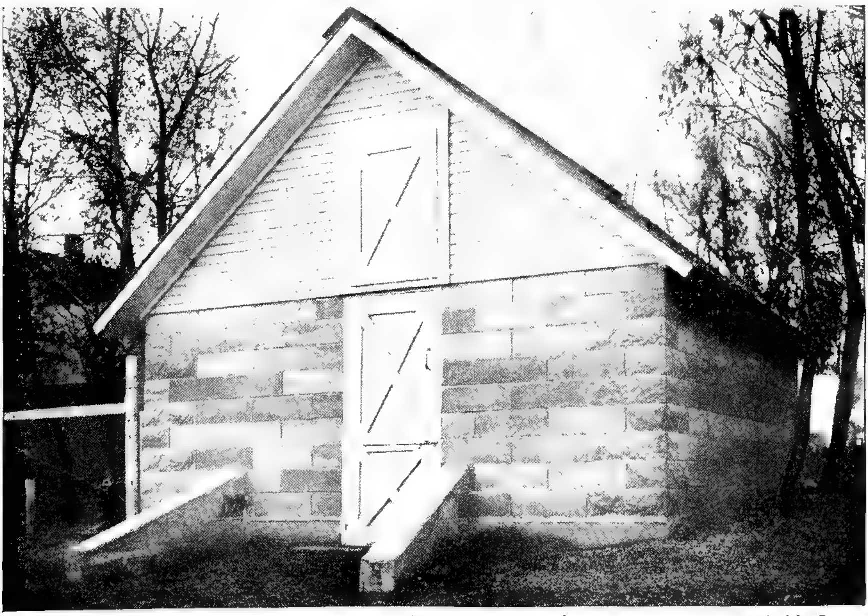


Figure 75. Concrete Block Ice House, Echo Valley Farm, Henry Hanson, proprietor, Odeboldt, Iowa. Built in 1907 by the owner. Size, 16 feet by 24 feet.

poor fire risks, and buildings of this kind seem to be attractive objects for lightning.

A concrete ice house is a good investment because when once properly constructed it will last for an indefinite period and will not warp out of shape, blow down or be destroyed by fire. The additional expense of conccrete construction, if there be any, will be entirely compensated during the first few years by the lower cost of up-keep and the freedom from repairs.

Capacity of the Farm Ice House. Solid ice weighs about 56 pounds per cubic foot and averages about 40 pounds per cubic foot, allowing for voids between cakes. On this basis a house 10 feet square and 10 feet in height would have a capacity of 20 tons, if carefully packed. This quantity will be found sufficient to take care of an average consumption of 500 to 700 pounds per week, for six months, allow-

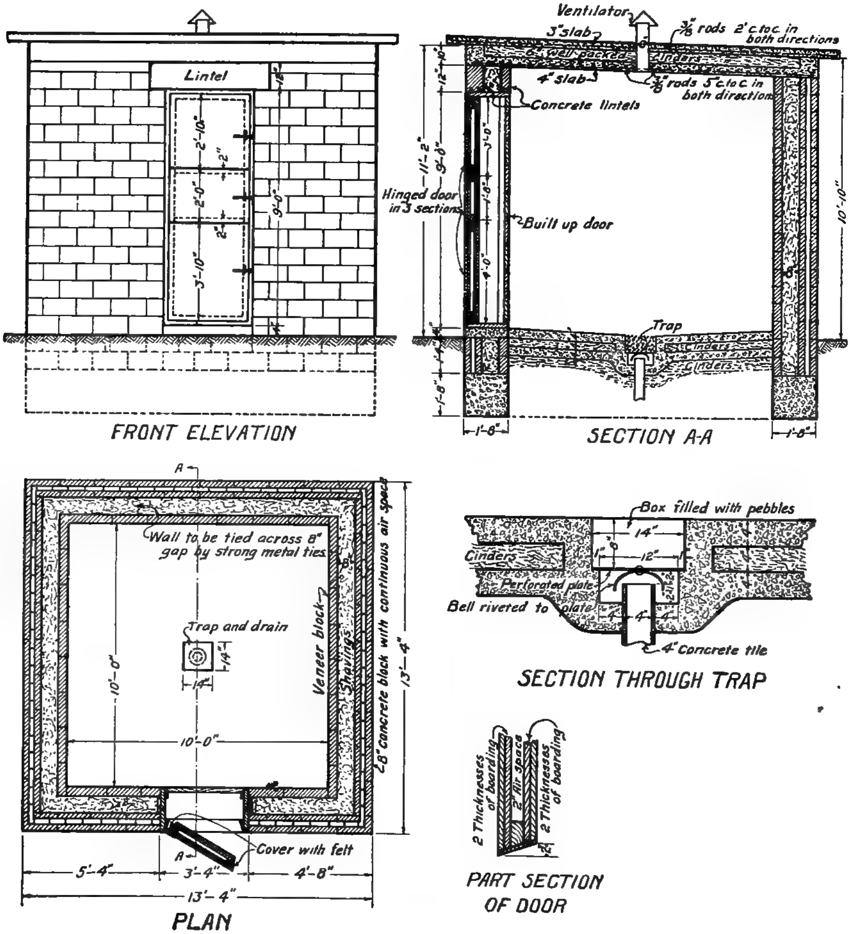


Figure 76. Concrete Block Ice House with double air space. A decidedly economical and practical structure.

ing liberally for shrinkage. Fifteen to twenty tons should be about the minimum capacity of the average farm ice house, and where plenty of cold water is not available for keeping the milk cool and for other purposes, it is advisable to build the ice house larger.

A Concrete Block Ice House

FIGURE 76 shows the design of a small concrete block ice house with walls having two air spaces. The inside of the building is 10 feet square by 10 feet in height and will hold from 15 to 20 tons of ice. The outer wall is constructed of hollow or air space concrete blocks and the inner wall of solid concrete veneer block. The floors and roof are also of concrete.

The foundation must go down below the frostline, and should extend up to within 16 inches of the ground line, at which point the first course of blocks should be started. The air spaces in the walls are thus brought down below the ground line, which insures better insulation against the heat than would be possible otherwise.

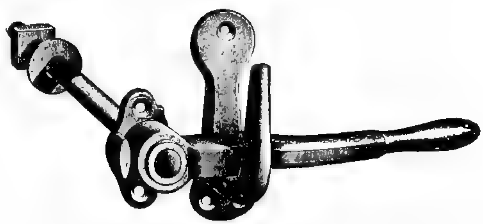


Figure 77. Common Clamp for closing ice house doors. A good clamp is very essential in keeping out air.

The walls have double air spaces and consist of an inner wall of solid veneer block 4 inches thick and an outer wall of 8-inch hollow block. There is an 8-inch air space within the two block walls. For maximum efficiency the hollow blocks should be of a continuous air space type similar to the Anchor block. The inner and outer walls must be tied together with metal ties made of strap iron or similar material at frequent intervals.

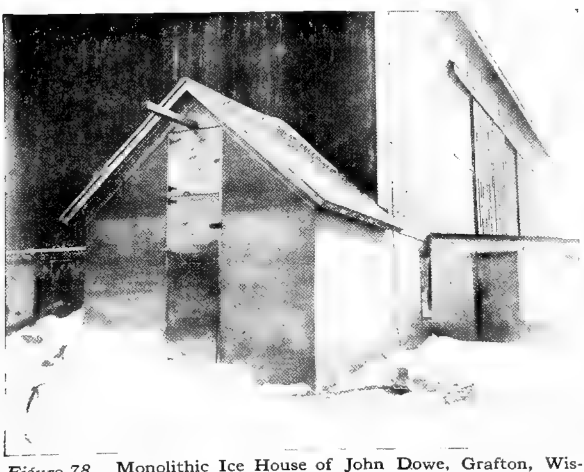


Figure 78. Monolithic Ice House of John Dowe, Grafton, Wisconsin. Size of ice room, 10 feet by 12 feet. Built by the owner.

Care must be taken to have the ties between the inner and outer walls extend only to the air space in the outer blocks, not continuing through to the outer surface, as steel is an excellent conductor of heat and cold and would readily conduct heat from the outside into the ice chamber. The space between the blocks may be filled with ground cork, dry shavings or sawdust, or left without filling.

Dry shavings probably make the cheapest and most satisfactory insulator. The joints between blocks should be well flushed in order to prevent the penetration of dampness, and a coating of tar or pitch on the side of the wall next to the insulating material is a good safeguard.

For the floor, the dirt should be excavated to a depth of a foot or more, if necessary to reach firm soil. Cinders should then be filled in and well packed, up to within 8 inches of the ground line. Two 4-inch layers of concrete are placed on this with an intermediate layer of cinders between, as shown in the figure. The floor should slope toward the drain in the center. The trap in the drain is necessary to prevent the circulation of air up through the ice. The design shown is simple and efficient, and no part of it will rust except the plate and the bell, which are both removable. The box opening is made with a wooden box form, and a 4-inch concrete tile should project about 3 inches through the center of the bottom. The plate, which is 14 inches square, permits the water to pass through. A bell, which hangs over the top of the tile when in position, is riveted to the center of the plate. Water will then stand in the box to the level of the top of the tile, effectually sealing the drain. The space above the plate is to be filled with pebbles or broken stone.

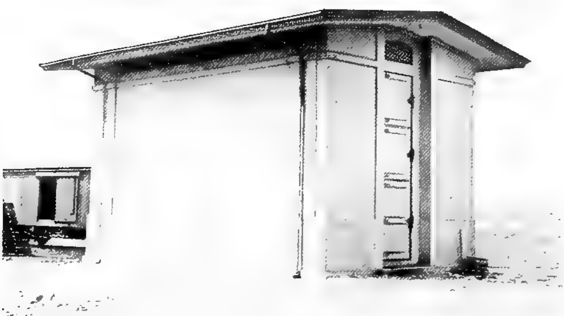


Figure 79. Ice House with Concrete Roof, Armour Farm, Lake Forest, Ill. A practical structure of pleasing appearance and permanent construction.

The roof consists of two concrete slabs with a layer of cinders between. The lower slab is designed to carry the load, being 4 inches thick and reinforced with $\frac{3}{8}$-inch round rods spaced 5 inches apart, center to center, in both directions. After the concrete has hardened sufficiently, 6 inches of cinders are placed upon it and covered with a 3-inch concrete slab reinforced with $\frac{3}{8}$-inch round rods spaced 24 inches apart, center to center, in both directions. A 6-inch galvanized iron ventilator should be placed in the center of the roof as shown.

Two doors are provided. The inner one is built up similar to a silo door and the sawdust and ice piled against it during filling. The outer one is built in three sections, each made up of a 2-inch skeleton frame covered on both sides with two thicknesses of tongue-and-grooved boards with tarred paper between. The edges should be covered with felt to insure a tight joint. The middle section opens first, and then either the upper or lower section as desired. This makes it unnecessary to open the door to its full height at one time, thus protecting the interior as much as possible from warm drafts.

While the ice above is being used, the space between the lower sectional door and the inner door may remain filled with shavings. Each door must have a latch of a type that will press the door inward in locking it. The type of latch shown in Figure 77, is recommended for this purpose.

Proportions (See page 157).

Foundation, Specification D.

Backing for hollow blocks, Specification C.
Floor, roof and lintels, Specification A.
Facing for hollow blocks, 1:2 cement and sand mortar.
Veneer blocks, 1:3 cement and sand mortar.

Table of Materials

	MIXTURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Foundation	1:3:5	22.3	2.50	67.5	4.14	111.7
Floor	1:2:3	17.7	1.32	35.7	1.96	52.9
Hollow Blocks { Backing	1:2½:4	52.7	4.84	130.6	7.78	210.0
Hollow Blocks { Facing	1:2	11.8	0.83	22.2	.....	.....
Veneer Blocks	1:3	53.5	5.93	160.2	.....	.....
Roof	1:2:3	33.2	2.48	67.0	3.68	99.3
Lintels	1:2:3	0.8	0.06	1.6	0.12	3.2
Total	....	192.0 (48 Bbls.)	17.96	484.8	17.68	477.1

Approximate amount of Reinforcing required:
450 Pounds (1200 feet) 3/8-inch round rods.

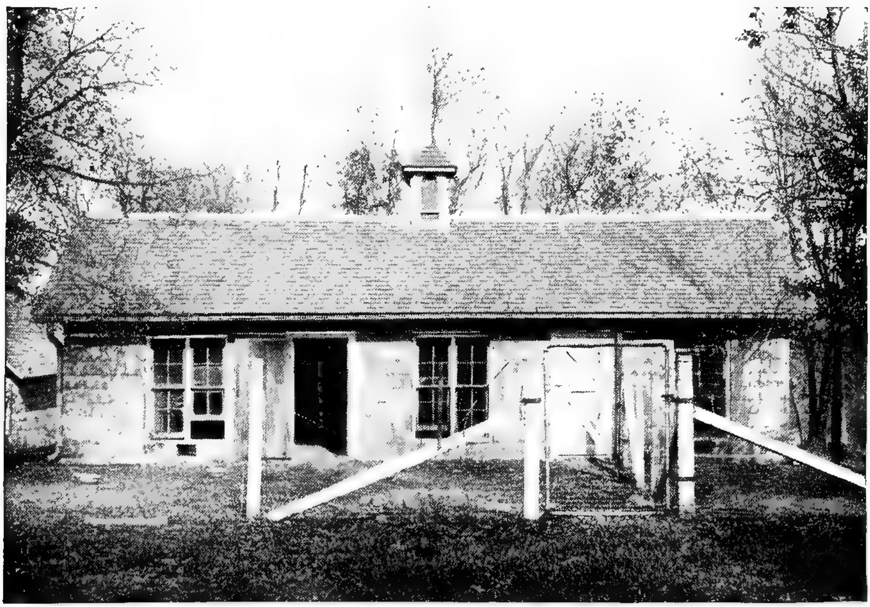


Figure 80. Concrete Block Poultry House, Echo Valley Farm, Odeboldt, Iowa. A comfortable house, in which the fowls lay all year around. Dimensions, 16 feet by 36 feet. Built by the owner in 1907.

Concrete Poultry Houses

WHETHER raising a few chickens for table use, or running an extensive poultry farm, there is generally a good margin of profit in poultry. The profit, however, varies in amount according to the favorable or unfavorable circumstances under which the fowls are raised and marketed. Briefly, poultry profits depend upon the following essentials:

(1) Suitable buildings, properly located.
(2) Careful feeding and breeding.
(3) Ability to hatch and rear chickens.
(4) Availability of markets.

In the present chapter only the first of the above requisites will be dealt with, discussion on the other three being not only outside the scope of this booklet, but covered in a complete and comprehensive manner in various Experiment Station bulletins.

Location of the Poultry House. The poultry house should be located on ground that is either naturally dry, or provided with good artificial drainage. The location of the house should be on a rise of ground, if possible, providing south exposure to insure plenty of sunlight. Buildings which face the south get the largest exposure to the sun's rays, and are warmer, dryer and more cheerful than buildings not so located. An eastern exposure is preferable to a western exposure, as hens prefer morning to afternoon sun.

Figure 81. Poultry House of H. Cox, Farmer City, Illinois, constructed of home made concrete blocks. Dimensions, 20 feet by 40 feet. Cost about $110.

The poultry house should be located, of course, with a view to saving time and labor in caring for the birds. Where a large number of fowls must be fed three times and watered once each day, and the house cleaned once daily, it need not be stated that the saving of even a few steps, by convenient location, results in no small saving of labor in the course of a year.

Requirements of a Good Poultry House. The two great requisites of a good poultry house are plenty of sunlight and an abundance of pure air. As a rule, poultry houses lack sufficient ventilation, which is far more important than warmth. Plenty of air insures the health of the poultry, but the arrangements of door and windows must always be such that drafts will be avoided, particularly in the vicinity of the roosts. Dampness in poultry houses, especially during cold weather, is generally the result of insufficient ventilation.

Sunlight is a great dispeller of disease, and the value of sufficient window area in poultry houses cannot be overestimated. It must be remembered, however, that while a house without plenty of sunlight is liable to be damp and dreary, a house containing excessive glass will be hot during summer days and extremely cold during winter nights.

Securing Proper Light and Ventilation. The best method of securing proper light and ventilation is by the combined use of cloth and glass windows. Roof or wall ventilators may also be used in conjunction, if desired. About one square foot of window area to ten square feet of floor area, about equally divided between cloth and glass windows, will be sufficient to give good light and ventilation if properly placed. In Bulletin No. 215 by the Wisconsin Agricultural Experiment

Figure 82. Monolithic Poultry House and Shop on the farm of Dr. D. S. Jaffray, Lisle, Illinois. One of several concrete buildings on Dr. Jaffray's place.

Station, Professors Halpin and Ocock give the proper amount of window space as one square foot of glass to fourteen or sixteen square feet of floor space, and the amount of cloth as one square foot to eight or ten square feet of floor space. Professors Rice and Rogers, in Bulletin No. 274, by Cornell University, recommend one square foot of glass surface for about 16 feet of floor area where the windows are properly placed, and used in conjunction with some other means of ventilating.

The same bulletin says: "The time when sunshine is most needed is when the sun is lowest, from September 21st to March 21st. Figure 83 shows the extreme points which the sunshine reaches during this period, through a four foot window placed with the top 4 feet, 6 feet and 7 feet high, respectively. With the highest point of the window at 4 feet, the direct sun's rays would never reach farther back than 9 feet; at 6 feet it would shine 13½ feet back, and at 7 feet it would strike the back side of the house a little above the floor. In very narrow houses

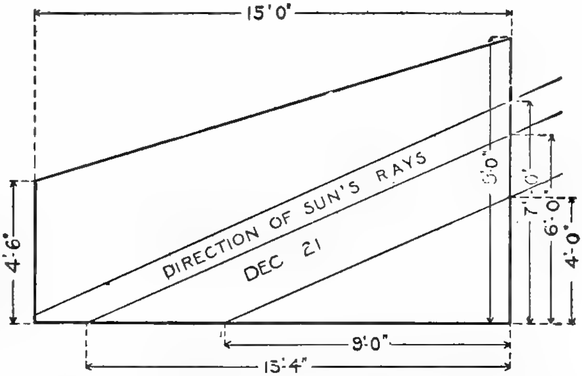


Figure 83. Diagram showing direction of sun's Rays December 21, and distance back which rays will penetrate for various heights of windows.

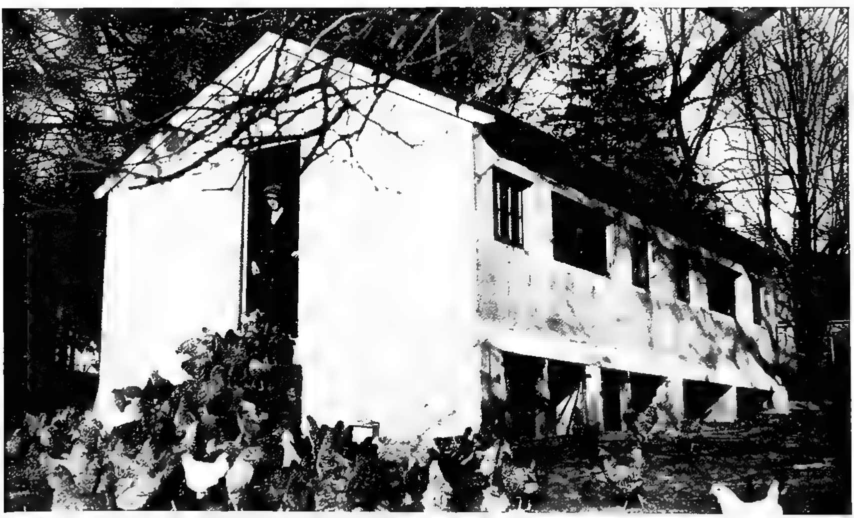


Figure 84. Reinforced Monolithic Poultry House of the Burn Brae Hospital, Primos, Pennsylvania. Built by the Superintendent, Dr. Stanton. Dimensions, 15 feet by 30 feet. Cost, $300. Dr. Stanton is so well pleased with this building that five more similar structures will be put up by the Hospital this year.

a window not higher than four feet above the floor would suffice. In houses deeper than 15 feet, however, the window should be placed even higher than seven feet in order to obtain the most desirable conditions.

Small glass in window-sash seriously obstructs the light. Very large lights break too easily and are expensive. Eight by ten is a good sized glass to be used in a 12-inch light sash, making it about 3 feet 9 inches high by 2 feet 5 inches wide."

Cleanliness and Convenience. The poultry house should be built in such a manner that it may be cleaned out easily and disinfected. The inside surface of the walls should be made smooth and free from ledges, projections or pockets. If care is taken with either concrete block or monolithic work, smooth walls will result without plastering. Litter accumulates rapidly and is hard to remove from square corners, and for this reason it is advisable to make all corners round, using the method shown in Figure 29, page 34. The windows should be placed where they will be protected and remain as free as possible from accumulations of litter.

Size of Building. Regarding the size of house to build, Wisconsin Bulletin No. 215 says "In determining the size of a house, consider the number of fowls that are to be kept in one pen. A flock of fifty hens should usually be allowed about five square feet of floor space per hen. Where the attendant is careful to keep the house clean and the floor heavily littered with straw, less floor space will be necessary. As a rule, it is far better to allow too much floor space than too little. The larger the pen, the less floor space will be required per hen. One hundred hens will thrive in a pen 20 x 20 feet, that is, four square feet of floor

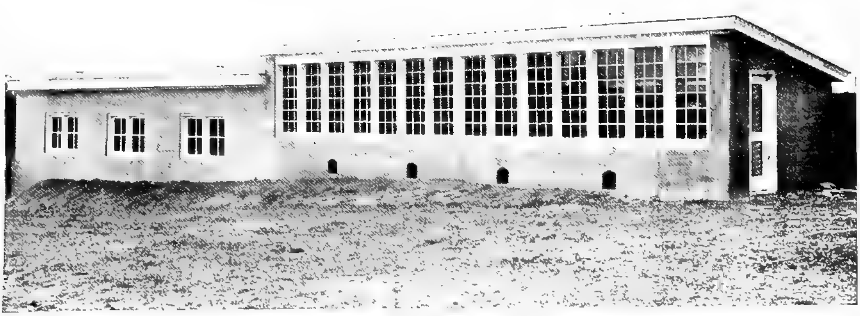


Figure 85. Concrete Poultry and Hog Houses, O'Neil Dairy Farm, Thiensville, Wisconsin. These buildings, which are of monolithic construction, are placed at a distance from the other structures and have excellent provision for light and ventilation.

space per hen, but one hen will not thrive in a pen 2 x 2 feet. In the large pen, each one has a chance to wander about over the entire floor space, thus getting more exercise. As the number in the flock becomes less, the amount of floor space per hen must increase, and anyone keeping eight or ten hens should allow at least ten square feet of floor space per hen, unless he is prepared to give special attention to cleaning and bedding the house. A crowded condition in a poultry house is responsible for lack of winter egg production."

Cornell Bulletin No. 274 says, "The best net results appear to be secured when fowls are allowed four or five square feet floor space each. Small flocks lay better than large flocks. While ordinarily we may expect to get more eggs from a small flock than from a large one it is also true that every time we double a flock we divide the labor. Fifty to one hundred fowls seem to be about as many as it is safe and economical to keep together in one pen as a unit."

Figure 86. Interior of Concrete Poultry House, O'Neil Dairy Farm, Thiensville, Wisconsin. Notice the light, sanitary construction, and the absence in the walls of cracks which harbor lice and mites.

Reinforced Concrete Poultry House for Several Flocks

THE monolithic house shown in Figure 88, may be built with as few or as many sections as desired to accommodate any number of flocks. As shown, this poultry house will furnish quarters for five flocks of about 35 birds each. The poultry compartments each consist of a room 9 feet 8 inches wide and 12 feet long, with a scratching pen of the same width and 6 feet long on the south side. The scratching pen is designed with a low roof with large glass windows on top making it warm and light and providing an excellent place for the chickens to scratch and pick up their food during cold and disagreeable weather.

Figure 87. Concrete Chicken House of W. F. Wickham, Pleasant View Poultry Farm, Center Point, Iowa.

The passageway is 3 feet 8 inches in width and runs the entire length of the building. Windows 2 feet 8 inches square are provided to furnish light, as in the preceding design. Details of the poultry room windows are shown in Figure 88, and Figure 89, section A-A. The window openings on the front side of the poultry room above the scratching pen roof are 2 feet 8 inches high and 3 feet 8 inches in length, and two are provided for each compartment. The openings in the scratching pen roof are 2 feet 8 inches by 4 feet 6 inches. Those on the front side of the scratching pen are 1 foot 10 inches by 3 feet 4 inches.

All of the windows excepting those on the front side of the scratching pens are of glass. Hot bed sashes with the glass put on in a manner similar to the shingles on a roof are the best to use over the openings in the roof of the scratching pen. Small windows below are made of muslin or canvas and serve as doorways for the chickens. The roosts and nests should be constructed as shown in the detailed construction (Section A-A) and described on pages 114 to 116.

In building the structure the walls may be run up simultaneously with a saving of a great deal of time, but less form lumber will be required if the various walls are built independently. The sidewalls are all identical in construction and one form will suffice for all. While the side walls are being built, one at a time, the back wall and the low front wall may be built. It is preferable to concrete the back wall at

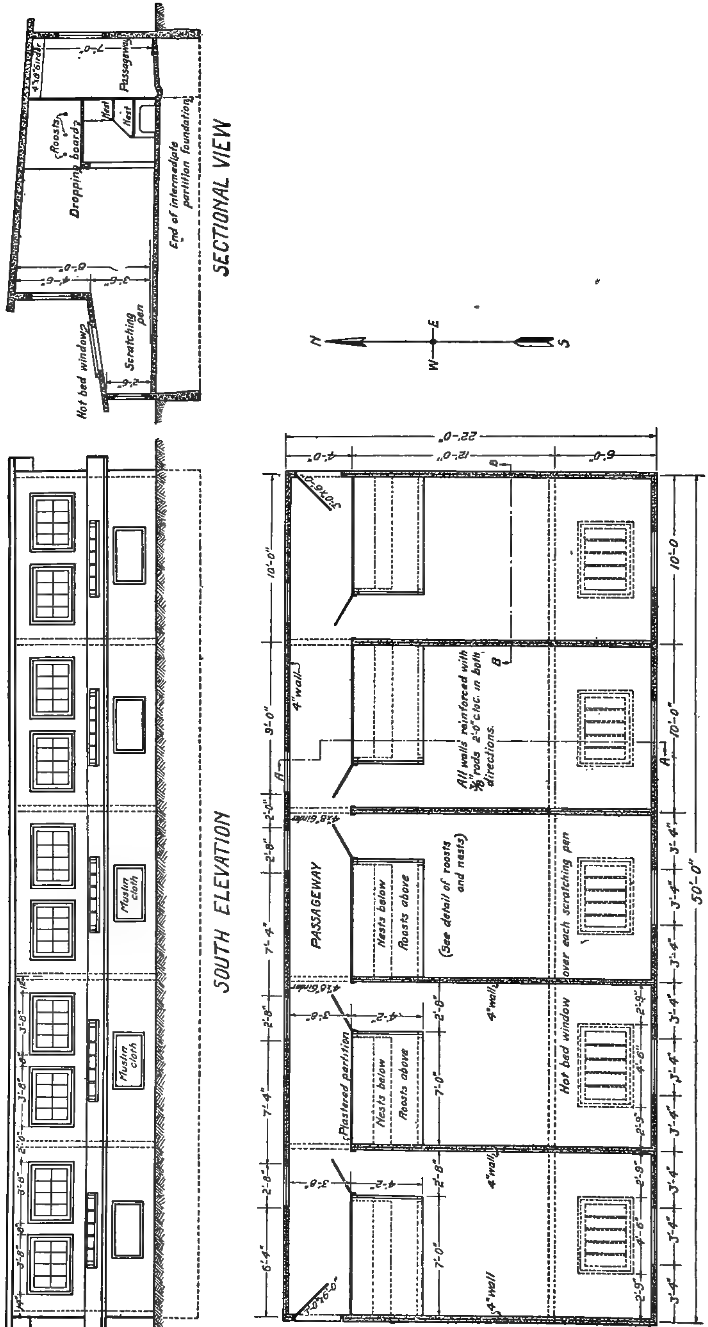


Figure 88. **Reinforced Concrete Poultry House designed to accommodate several flocks. A fire-proof and vermin-proof structure of the most approved type.**

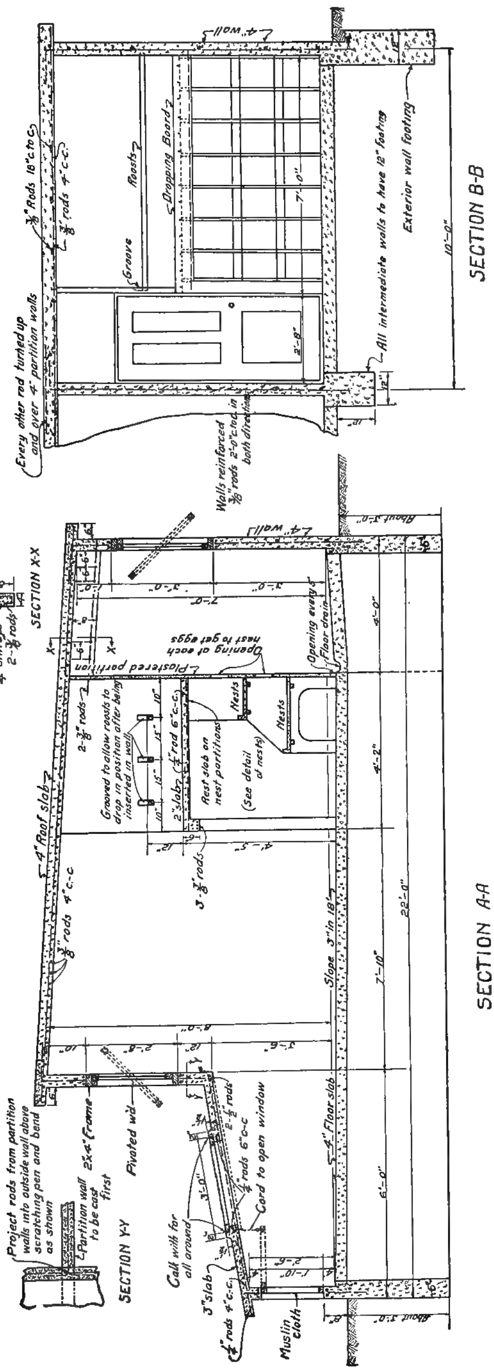


Figure 89. Sectional Views, Reinforced Concrete Poultry House.

one operation, but if this is impossible it may be built in sections taking care to secure a good bond between the old and the new concrete wherever the work has been discontinued. The method of joining old work to new is described on page 36.

In completing the side walls and the back wall the reinforced girders spanning the passageway should be cast in place. These girders are 8 inches deep, 4 inches wide, and 4 feet 4 inches long, and require only a simple box mold. The girders should be reinforced with two $\frac{3}{8}$-inch rods placed one inch above the bottom, and four $\frac{1}{4}$-inch stirrups placed as shown in section A-A and section X-X, Figure 89. The $\frac{3}{8}$-inch reinforcing rods should be long enough to be securely anchored in the concrete at both ends of the girder. When these girders are placed in the walls the tops should be flush with the top of the walls. All of the walls should be reinforced according to the standard reinforcing directions given on pages 39 to 44, with the modifications shown in the figures.

Vertical reinforcing rods in the walls should extend about 6 inches above the top of the wall for the purpose of joining the roof reinforcing. If the end walls are not constructed at the same time as the side walls, corner reinforcing should be placed in the side walls so as to extend into the end walls when they are concreted later.

The construction of the building will be found more simple if the scratching pen roof and the front wall above it are left until the completion of all the other walls. Forms for the scratching pen roof should only consist of a tight floor of boards, a suitable wooden frame for making the opening in the top of the roof, and a small mold box for casting the eave. The wall above the scratching pen roof requires only a simple wall form with frames in it to produce the desired window openings. The most economical manner of casting this roof wall is to provide a form for just one section and to take down the form and move it to the next section as the section previously concreted becomes strong enough to warrant removal of the forms.

If this method be used, the lengthwise reinforcing should not be discontinued at the end of each section, but should run continuously from one end of the roof to the other, the roof only being broken where

Figure 90. Concrete Poultry House on the 5-acre poultry farm of Karl Selig, Downer's Grove, Illinois. Each of the two wings of the house have quarters for five flocks. The center portion of the building is occupied by the owner.

necessary, and there lapped in accordance with the suggestion made on page 140. The roof slab is 3 inches thick and is reinforced with ¼-inch rods spaced 6 inches apart, center to center, the entire section of the roof; and ¼-inch rods spaced 4 inches apart, center to center, the short way of it. These rods should be wired together and placed in the roof in accordance with suggestions on page 65.

The wall above this roof should be 4 inches thick, reinforced as shown in section A-A, Figure 89, with two ½-inch rods running lengthwise of the wall one inch above the bottom of it, and with corner reinforcing extending up from the scratching pen roof and extending from the wall into the main roof above. Additional reinforcing should be placed around the windows as suggested on page 41. Section Y-Y shows the method of joining this wall to the partition walls.

The main roof of the house should be constructed in accordance with the suggestions furnished in the section on roofs, and the forms shown in Figure 52 will be found suitable for use in this case. Reinforcing consists of ⅜-inch rods placed 4 inches apart, center to center, the long way of the roof, and ⅜-inch rods spaced 18 inches apart, center to center, the short way of the roof. Although this roof may be constructed in sections in the same manner as that suggested for the small roof below, the reinforcing should be continuous from one end of the roof to the other. Great care must be taken in joining one section of the roof to the other to obtain a good bond between the old and new concrete. (See page 65.) Care should be taken to discontinue roof slabs directly over the center line of the partition walls which support it.

Proportions (See page 157).
Foundations and footings, Specification D.
Floor and roof slabs, Specification A.
Roof girders, Specification B.
Walls, Specification C.

Table of Materials

	MIXTURE	ONE ROOM				EACH ADDITIONAL ROOM			
		Concrete Cu. Yds	Cement Sacks	Sand Cu. Yds.	Stone Cu. Yds.	Concrete Cu. Yds	Cement Sacks	Sand Cu. Yds	Stone Cu. Yds.
Footings and Foundations	1:3:5	6.04	28.0	3.14	5.19	3.33	15.4	1.73	2.86
Walls	1:2½:4	4.02	22.4	2.05	3.30	2.58	14.4	1.32	2.12
Roof Slabs	1:2:3	2.94	20.5	1.53	2.26	2.75	19.2	1.43	2.12
Floor	1:2:3	2.55	17.8	1.33	1.96	2.55	17.8	1.33	1.96
Girders	1:2:4	.03	0.2	.01	.03	.03	0.2	.01	.03
Totals	.....	....	88.9 (22 1-4 Bbl.)	8.06	12.74	....	67.0 (16 3-4 Bbls.)	5.82	9.09

FOR ONE ROOM

1485 feet ⅜-inch rods........Weight 558 Lbs.
283 feet ¼-inch rods........Weight 48 Lbs.
Total....................606 Lbs.

FOR EACH ADDITIONAL ROOM

1248 feet ⅜-inch rods........Weight 468 Lbs.
290 feet ¼-inch rods........Weight 50 Lbs.
20 feet ½-inch rods........Weight 14 Lbs.
Total....................532 Lbs.

(Add 10 per cent additional to allow for waste.)

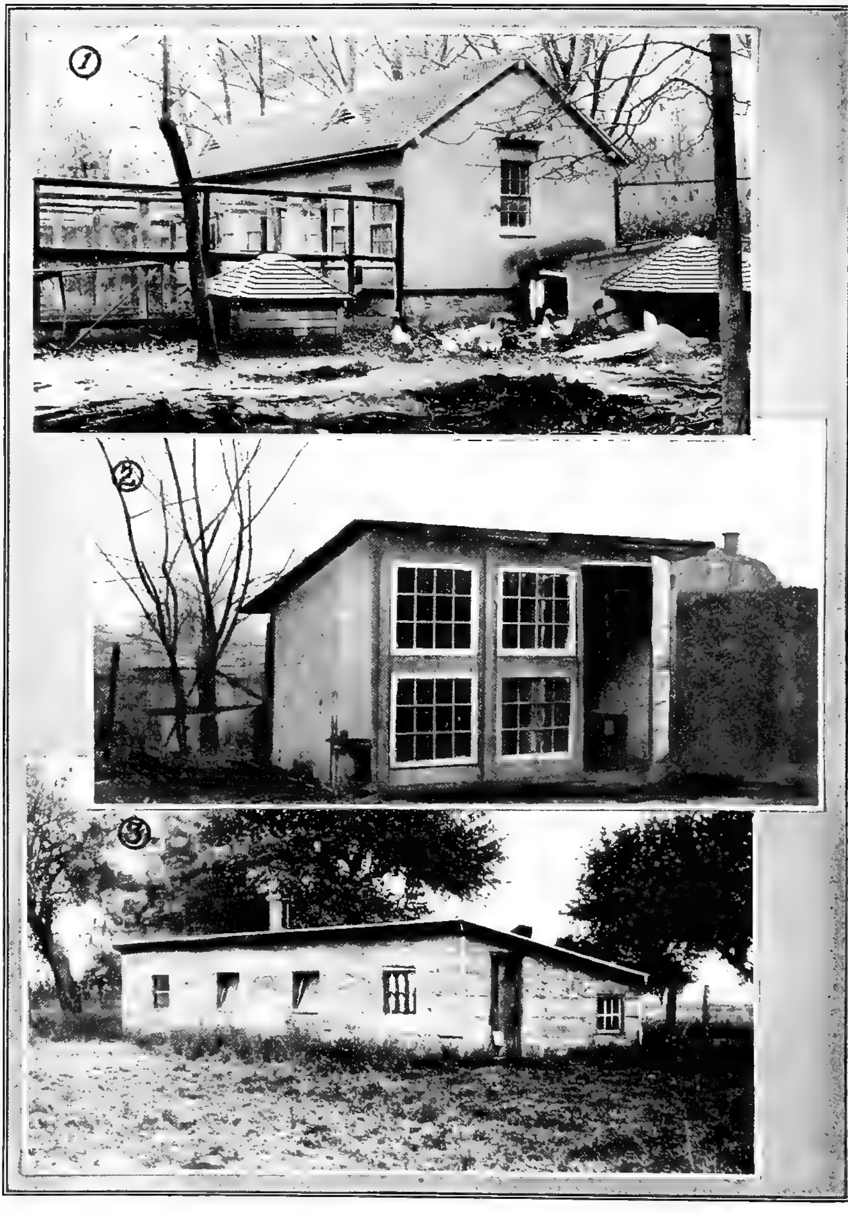


Figure 91. CONCRETE POULTRY HOUSES

(1) Cement Plaster Poultry House of W. D. Dengre, West Manchester, Mass.
(2) Concrete Poultry House of R. E. Griffith, Haverford, Pa.
(3) Dr. N. Baldwin's Concrete Poultry House, Coldwater, Michigan.

Concrete Block Poultry House

IN putting up a poultry house the owner frequently has in mind future additions or alterations to give the house greater capacity. The concrete block building shown in Figure 93 is designed to accommodate a flock of thirty-five or forty chickens, but is so planned that it may be enlarged to accommodate any number of birds desired, by simply adding additional rooms of the same size onto either side of the structure.

The poultry compartment is 11 feet 8 inches from the hallway to the front, and 12 feet 4 inches from side to side. The hallway is divided off from the poultry compartment by a cement plaster wall, directions for the building of which will be found on pages 52 to 57. Light and ventilation are provided in the poultry compartment by a large window in the front, 6 feet 8 inches in height and 5 feet 4 inches in width. The window which should swing on a vertical axis or from hinges attached to the top of the frame, should be covered with heavy muslin or light canvas.

Two doors are shown leading into the house from the outside, but only one is required if just a single section of the house is built. If more than one section is built it is convenient to have a door at each end of the hallway. It is also necessary to provide a door between the hallway and the poultry room, although none is shown in the figure. Light is provided in the hallway by a glass window 2 feet 8 inches square, for each section of the house.

Figure 92. George Rosenhauer's Poultry House, Early, Iowa. In spite of outside cold the fowls are kept in good condition and lay all winter.

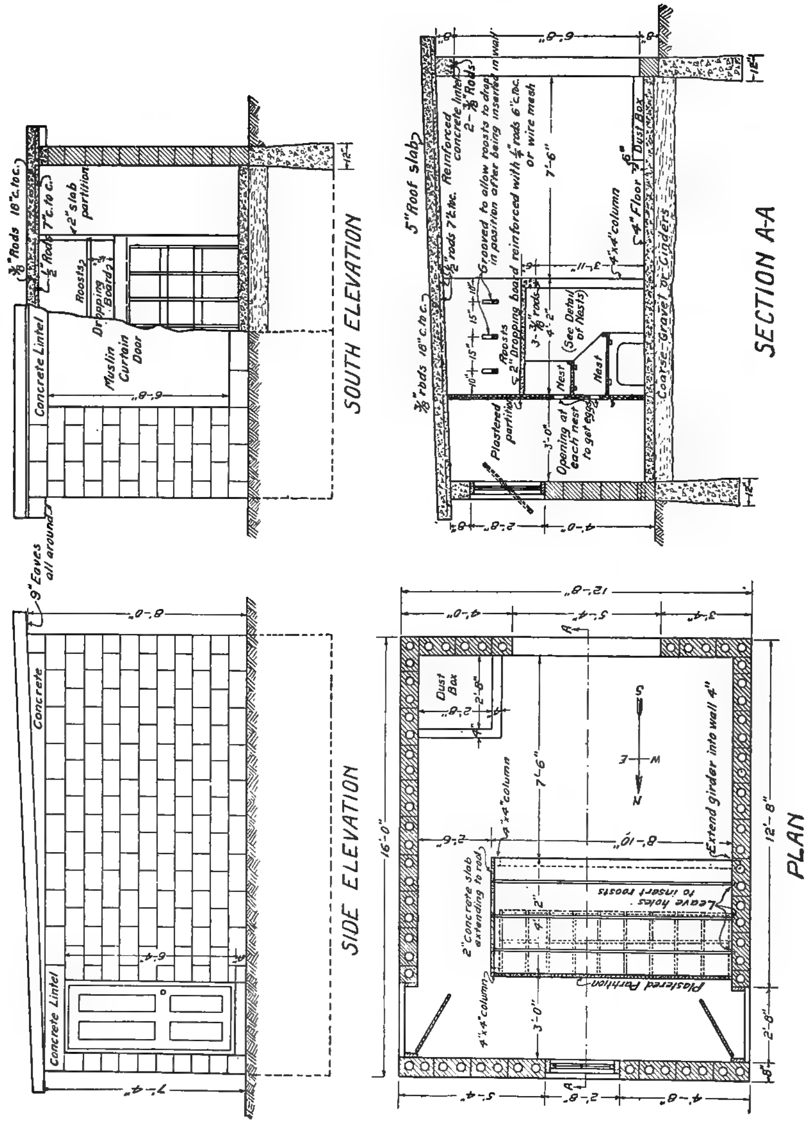


Figure 93. Concrete Block Poultry House which may be enlarged to accommodate additional flocks by duplicating the structure as shown.

The foundations, floor, walls and roof of the house may be constructed in accordance with the design shown in the figure and the general directions for such work given in the first section of this book. The roof slab is 5 inches thick, reinforced with ½-inch round rods, spaced 7 inches apart from side wall to side wall, and ⅜-inch round rods 18 inches apart from front to back. The ½-inch rods should be placed 1 inch above the bottom of the slab, and the ⅜-inch rods laid on top of, and wired to them. The lintel above the window opening on the front side of the house should be 6 feet 8 inches in length, reinforced with two ⅜-inch round rods placed one inch above the bottom of the lintel.

The concrete roosts, nests, and dust box should be constructed as suggested under the head of "Interior Fittings of Poultry Houses," pages 113 to 116. Openings are left in the cement plaster partition between the hallway and the poultry compartment through which to gather the eggs without entering the room with the poultry. These openings may be covered with a wooden or screen door, or a number of individual doors, to prevent the hens from coming out through them.

Proportions (See page 157.)

Footings, Specification D.

Body of blocks, Specification C.

Roof, floors and lintels, Specification A.

Plaster Partition and Surface Coat for Concrete Blocks, 1:2 cement and sand mortar.

Table of Materials

	VOL. Cu.Yds	MIXTURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Footings	5.18	1:3:5	24.0	2.69	72.7	4.45	120.3
Blocks — Body	......	1:2½:4	29.4	2.70	73.0	4.32	116.6
Blocks — Surface	......	1:2	6.2	.46	12.4	......	.....
Lintels	.31	1:2:3	2.2	.16	4.3	.24	6.5
Roof	3.85	1:2:3	26.8	2.00	54.1	2.96	80.0
Plaster Partition	.42	1:2	5.2	.39	10.5	......	.....
Floor	2.06	1:2:3	14.3	1.07	28.9	1.59	42.8
Total	....	......	108.1 (27 Bbls)	9.47	255.9	13.56	366.2

Approximate amount of Reinforcing required:

650 feet ⅜-inch round rod.................. Weight 245 Lbs.

(Add about 10 per cent additional to allow for waste.)

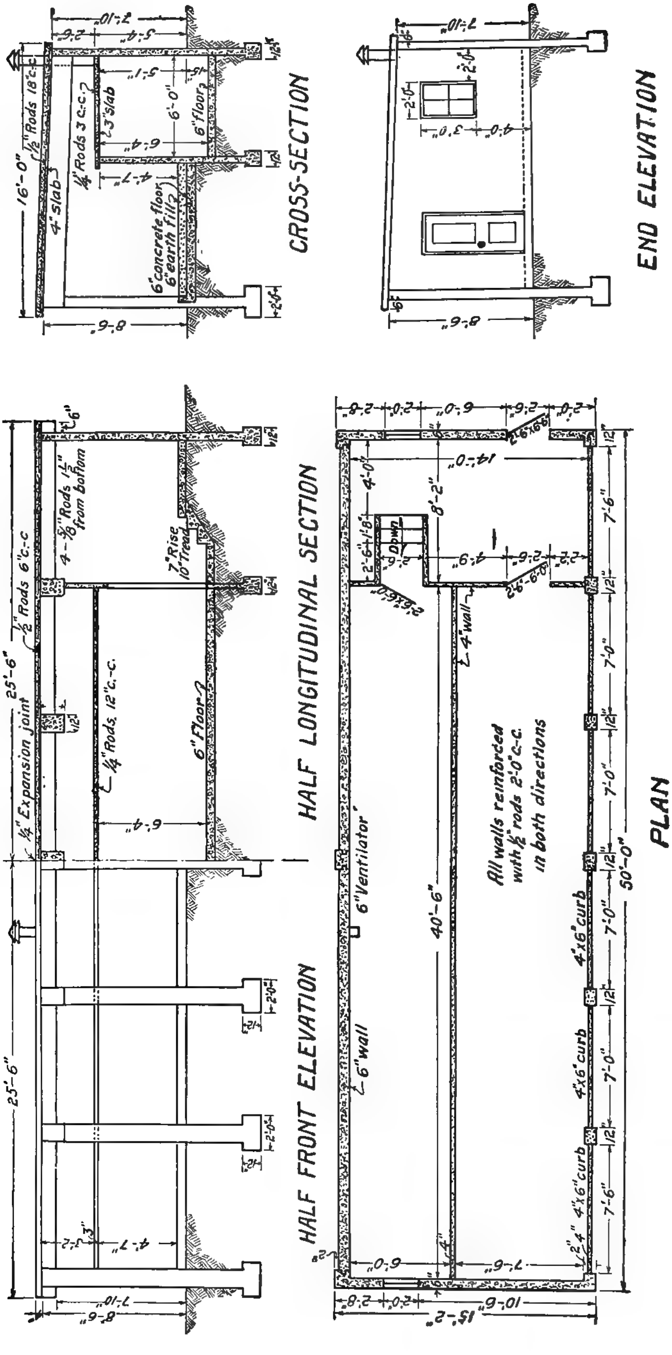


Figure 94. **Reinforced Concrete Poultry House with Incubator Cellar, designed for I. S. Hamilton, West Bridgewater, Pennsylvania.**

Reinforced Concrete Poultry House with Incubator Cellar

AN incubator cellar is frequently a desirable adjunct to the poultry house, and where it is desired to provide space for the incubators in the same building in which the poultry is housed, the design shown in Figure 94 will be found convenient. This building was designed for F. S. Hamilton, West Bridgewater, Pa., from suggestions furnished by him. It has a poultry compartment 7 feet 6 inches in width and 40 feet 6 inches in length, with a loft on one side 6 feet in width and extending the entire length of the poultry compartment.

The roosts may be placed in the loft. The incubator room is three steps below the floor of the poultry room, and is 6 feet in width and 40 feet 6 inches in length. A vestibule or storeroom 14 feet by 8 feet 2 inches is provided at the end of the building with doors leading to both compartments. One side of the poultry room is open, the roof of the structure being supported on the open side by columns. The openings between columns should be provided with muslin or canvas curtains which can be lowered to give sufficient warmth during cold weather.

A low curb should be built between the columns on the open side of the poultry room to prevent the dirt on the floor from being scratched out. The method of construction and dimensions of this curb are given in Figure 94.

The footings for the walls are 12 inches wide, and those for the columns are 18 inches wide. The walls of the structure are 6 inches thick and extend around three sides. A 4-inch concrete panel wall 7 feet 6 inches long extends between the two columns at the right end of the structure, forming the fourth side of the feed room. The columns which support the roof on the fourth side are 8 inches by 12 inches in section and are reinforced with four ½-inch round rods placed 1½ inches in from the corners of the columns. These columns support the

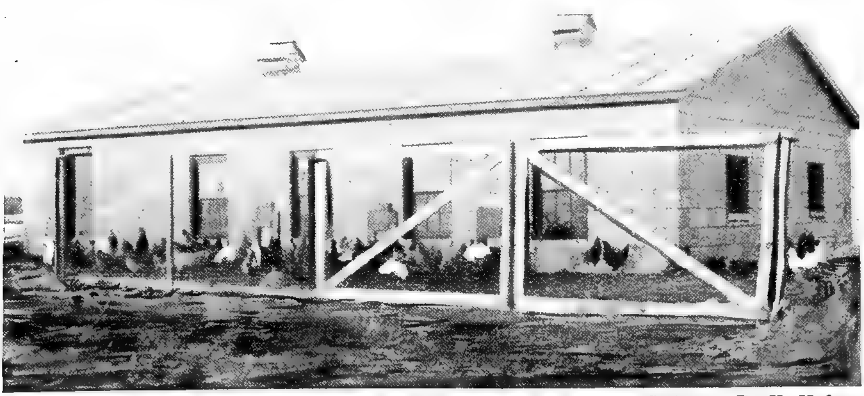


Figure 95. Home of A. L. Larson's prize flock, near Aberdeen, South Dakota. R. K Hafsos, Contractor.

roof girders which in turn support the roof slabs. The wall on the long side of the building is broken into two panels between which is placed a column slotted as shown in the illustration. This column is added for the sake of appearance only, and if it is desired to omit the column an expansion joint should be left at this point as directed on page 36. The end walls are tongued to the back wall as shown. The slab above the incubator cellar is 3 inches in thickness and is reinforced with ¼-inch rods spaced 3 inches, center to center, across the short way of the slab, and about 24 inches, center to center, lengthwise of the slab. Forms for the slab should be constructed at the same time as those for the walls, and the slab and walls, up to the slab, concreted at the same time. The back wall of the building may then be carried up to the roof line.

If the roosts are placed in the loft above the cellar roof, the roof slab will serve as a dropping board. The roof girders are 12 inches wide and 16 inches deep, reinforced with four ⅝-inch rods placed 1½ inches back from the corners as shown. They are cast in place in mold boxes at the same time as the roof slabs.

Proportions (See page 157).

Foundations and column footings, Specification D.

Curbs, stairs, walls, partitions, Specification C.

Floor and roofs, Specification A.

Columns and beams, Specification B.

Table of Materials

	Conc. Cu.Yds	MIX-TURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Foundation	9.15	1:3:5	42.5	4.76	128.5	7.87	212.5
Column Footings	1.49	1:3:5	6.9	.77	20.8	1.28	34.6
Floor	12.54	1:2:3	87.3	6.52	176.1	9.66	260.7
Curb	0.25	1:2½:4	1.4	.13	3.4	.21	5.5
Stairs	0.11	1:2½:4	.6	.06	1.5	.09	2.4
Walls	13.15	1:2½:4	82.6	5.78	156.2	11.56	312.4
Partitions	4.02	1:2½:4	22.4	2.05	55.4	3.30	89.0
Columns	0.91	1:2:4	5.7	0.40	10.8	0.80	21.6
Beams	4.22	1:2:4	26.5	1.86	50.0	3.92	105.8
Cellar Roof	2.44	1:2:3	17.0	1.27	34.3	1.88	50.7
Roof	10.01	1:2:3	69.7	5.21	140.5	7.71	208.1
Total	.....	......	362.6 (90¾ Bls)	28.81	777.5	48.28	1303.3

Approximate amount of Reinforcing required:

3140 feet ½-inch rods	Weight 2094 Lbs.
511 feet ⅜-inch rods	Weight 192 Lbs.
1318 feet ¼ inch rods	Weight 220 Lbs.
340 feet ⅝-inch rods	Weight 355 Lbs.
Total	2861 Lbs.

Interior Fittings for Concrete Poultry Houses

Floors. A concrete floor is a very desirable feature in a poultry house, being durable and rat-proof, and easy to keep clean. The floor may conveniently be laid as soon as the foundation is in place, following closely the directions given in the section on "Concrete Floors," pages 23 to 26. The floor should be placed at a sufficient height above the level of the ground to prevent water from running in, and the surface should be troweled quite smooth, to facilitate cleaning.

The concrete poultry house floor should never be left bare, but should be covered with about three inches of sand or soft dirt. This should be replaced as often as necessary to keep it fresh and clean at all times. The sand should be covered with six to ten inches of straw in the winter. Besides providing warmth for the fowls, the straw makes it necessary for them to scratch harder for their feed, giving them needed exercise during cold weather.

Sand Bath. If it is impossible to secure sand in sufficient quantity to use on the entire floor, a space 2½ feet square should be curbed off in one corner of each section of the house, to be used as a sand bath for the fowls. The sand within the curbing should be kept dry and clean, and in case sand is not available, finely powdered ashes are sometimes substituted. The principal objections to ashes, however, are that they are likely to contain sharp particles which have a tendency to cut the down on the feathers, and that their attraction for moisture makes it necessary to change ashes oftener than sand.

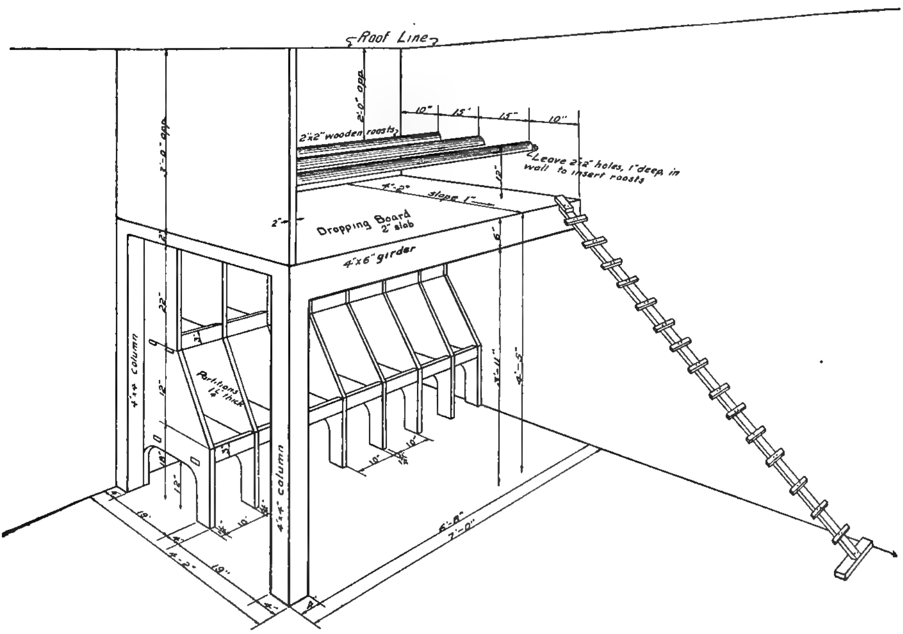


Figure 96. **Perspective view showing concrete hens' nests and dropping board in position.**

The curb around the sand bath should be put in at the same time as the floor, and for this work only simple form boards are required. Four inches will be found a convenient width for the curb, which should extend up above the floor about the same distance.

Roosts. A simple wooden ladder will serve as an approach to the roosts. The dropping board should consist of a concrete slab 2 inches thick and should be given a slop of 1 inch to the foot, to facilitate cleaning. The roosts are made of 2x2-inch wooden strips which fit into 2x2-inch pockets in the wall on one side and into a little shoulder with a recess for support on the other side. This scheme makes it possible to remove the roosts for cleaning and disinfecting.

Nests. Concrete is a very good material for use around poultry houses, because of the fact that it contains no crevices to harbor vermin. Experts declare they have found no case where a setting hen has left a concrete nest because of lice. This freedom from lice makes it possible for the bird to retain more flesh at the end of the setting period and therefore, more strength. The little chicks are accordingly stronger because they are not hatched in the breeding place of hungry lice.

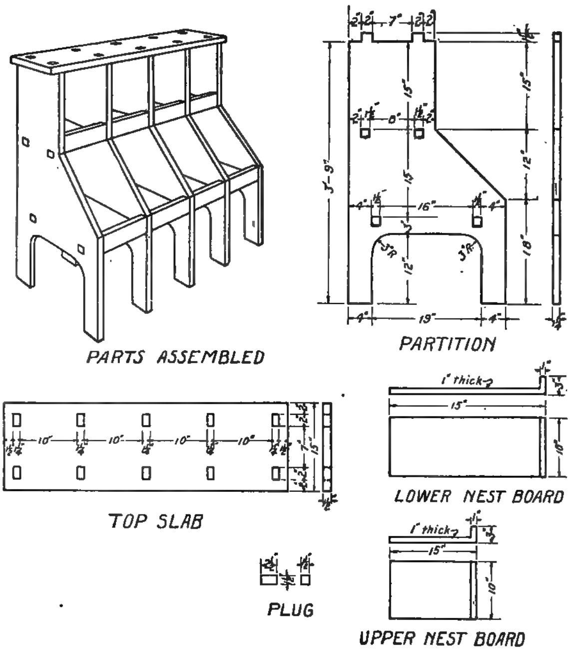


Figure 97. Plan for a Battery of Concrete Hens' Nests, suitable for use in Concrete Poultry House.

Figures 96 and 97 show the plan and detail for making concrete hens' nests. This scheme is applicable to any hen house as the individual parts are made separately and erected in place. The concrete nests are constructed as follows: the 4 x 4-inch column, 4'x 6-inch girder, and the dropping board should be cast in one operation. The 2-inch slab to the left (Figure 96) may be cast separately and put in place later. This slab extends to the roof and is intended to prevent drafts from reaching the chickens on the roosts.

The sides of the nests may be cast in unit sections in a mold similar to that shown in Figure 43. The top end of the nest partitions are provided with two projections, which fit into corresponding openings in the concrete slab directly above, (shown in Figure 97,) and are sealed with concrete mortar after being placed in position. The lower nests

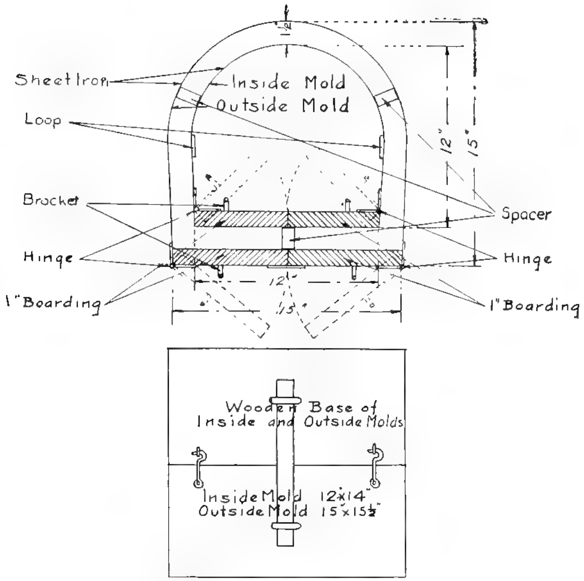


Figure. 98. Mold for making individual hen's nests for outside use. Hens do not abandon lice-proof nests and chicks do not become the prey of a legion of hungry lice.

Figure 99. Concrete Hens' Nests and Molds of John Christensen, St. Charles, Illinois. Mold made by B. M. Bangs & Co., Lake Mills, Iowa. The two objects to the left are the outer and inner molds, while front and back views of the nests are shown to the right.

project beyond the upper nests as shown, making it possible for the hens to fly to the higher nests without difficulty.

The bottom boards for the nests are cast separately as shown in Figure 97, the slab being 1 inch thick with a projection across the front 3 inches thick. This projection serves as a perch for the birds to light upon and prevents the eggs from rolling out of the nest. The bottom of the nests slip in between the partitions, and are supported by little concrete lugs which slip into mortices cast in the partition. At the rear of the room, directly back of the nests, there should be an alleyway 4 feet wide. By means of holes in the partition wall, it is possible to remove the eggs from the nests from this alleyway.

Figure 100. Concrete Poultry House of C. W Boynton, Chicago. Cement plaster construction on woven wire lath supported by a framework of concrete columns and beams.

Figure 99 shows a concrete nest for outside use. Such nests are valuable because they can be placed anywhere, are water-proof and vermin-proof, and are practically unbreakable. The forms for making these nests are manufactured by B. M. Bangs, Lake Mills, Iowa.

Figure 101. Interior of Concrete Poultry House, Iowana Farm, Davenport, Iowa. The model home of Col. French's fine flocks of White Orpingtons.

Concrete Hog Houses

THE United States raises nearly one-half of the world's supply of swine. The price of pork has advanced steadily during the past two or three decades, and the future trend of figures will undoubtedly be upward. The increasing value of pork products should find hog raisers alert to stop every loss. It is at once an argument for hog saving as well as hog raising. With the proper care and attention, and the hogs housed in healthful and sanitary quarters, there is no reason why much of the annual loss of swine flesh cannot be stopped, and the profits of hog breeders proportionately increased.

F. G. Moorhead, writing on the present campaign to stop the needless slaughter of young pigs in Iowa, says in a recent number of the Technical World Magazine : "It was the average of twenty-five pigs lost on each farm each year which wrinkled most of the experts' brows, for there are 209,000 farms in Iowa, which means that 5,000,000 little porkers give up the ghost uselessly each year." If reliable, these figures are astounding in themselves, but even greatly more so when it is considered that conditions similar to those in Iowa hold in almost every hog-producing state in the Union.

The introduction of concrete about the hog pen has been productive of excellent results, both by improving the conditions under which the swine are housed and fed, and by making possible a saving in labor,

Figure 102. **Hog House of John E. Holden, Carson, South Dakota, built of Defiance concrete blocks. The owner found this material cheaper than wood and of course more sanitary and permanent.**

maintenance expenses and feed. The general use of concrete for breeding houses, shelters, troughs, wallowing pools and feeding floors should bring about even further economies, as well as raise the standard of the stock and prevent much of the large loss of young pigs, due to exposure, unsanitary conditions and accidental death. Recent Government bulletins on the subject of hog tuberculosis point clearly to decaying wood construction as a chief source of infection.

Notwithstanding the advice of swine experts generally, a large proportion of our farmers provide nothing more than a sheltered pen in which to keep their hogs during cold weather. In such cases the sows are not bred to farrow until late; or if they do farrow early, the loss of pigs is large. February and March pigs are, as a rule, the most profitable, and to successfully raise these in the northern states requires a tight, substantial house, often equipped with provision for heat.

During the winter of 1903-04 a series of interesting experiments were conducted by the Central Experimental Farm, Ottawa, Canada, to determine the comparative economy of wintering hogs within the piggery and without. Results show that a number of brood sows kept in a warm house were maintained in good condition at 25 per cent less expense than an equal number of sows wintered in the shelters occupied during the summer. The cost of feeding nine fall pigs kept within was found to be $3.85 per hundred pounds increase in live weight, while that of feeding eleven fall pigs maintained without was $5.42 per hundred pounds increase. Besides this saving of 29 per cent in actual cost of feed, the pigs kept within gained in weight somewhat faster than those kept without.

Figure 103. Concrete Block Machine Shed and Hog House on the farm of Fred Rownd, Cedar Falls, Iowa. Permanent buildings of pleasing appearance and practical design.

Types of Concrete Hog Houses. In the following pages designs for three general types of hog houses are shown: First, those used merely as shelter houses; second, the small breeding houses, used principally for early litters; third, a large house designed to accommodate a score or more of brood sows. Explanations of the available methods of construction—monolithic, block, panel and cement plaster—are given in the preceding chapters, while the necessary instructions for applying stucco coats to wooden, brick or concrete block buildings will be found on pages 52 to 57.

Small Shelter House of Unit Construction

THE accompanying diagram, Figure 105, shows a plan and elevations of a small shelter house (17 feet 6 inches by 9 feet 1 inch). The walls and roof of the house are supported on 8 x 8-inch reinforced concrete posts, and placed 8 feet 5 inches apart, center to center. The posts used on the front of the structure are 9 feet long, and those used on the back 8 feet 5 inches long, the roof thus being given a 6-inch slope. The posts are each reinforced with four ½-inch round rods, which are laced together diagonally with wire, for the purpose of strengthening the walls of the grooves. Recesses are provided to receive the wall slabs, each recess being 2 inches deep, 2¾ inches wide at the surface, 2½ inches wide at full depth, and extending from the upper end of the column to a point 3½ feet from the lower end.

In making the post or beam, the mold should be placed as shown, and concrete made of one part cement to two parts coarse sand to four

Figure 104. **Hollow Wall Monolithic Hog House of Charles Rauner, Laramie, Wyo. The building is 16 feet by 42 feet, with a height of 12 feet to the ridge of the roof. It is designed to contain 8 pens on each side of a center passageway.**

parts screened gravel or crushed stone put in to a height of one inch. Two reinforcing rods are then placed upon the concrete, wires being passed around the rods at intervals of 18 inches, and the ends twisted together and brought up diagonally. The mold is then filled with concrete to within an inch and a half of the top, the remaining two reinforcing rods laid upon this, and the diagonal wires brought out and twisted around them. The mold is then completely filled. A 1:2:4 mixture will give ample strength, but if it does not give sufficiently smooth surfaces, the proportion of stone should be decreased until the

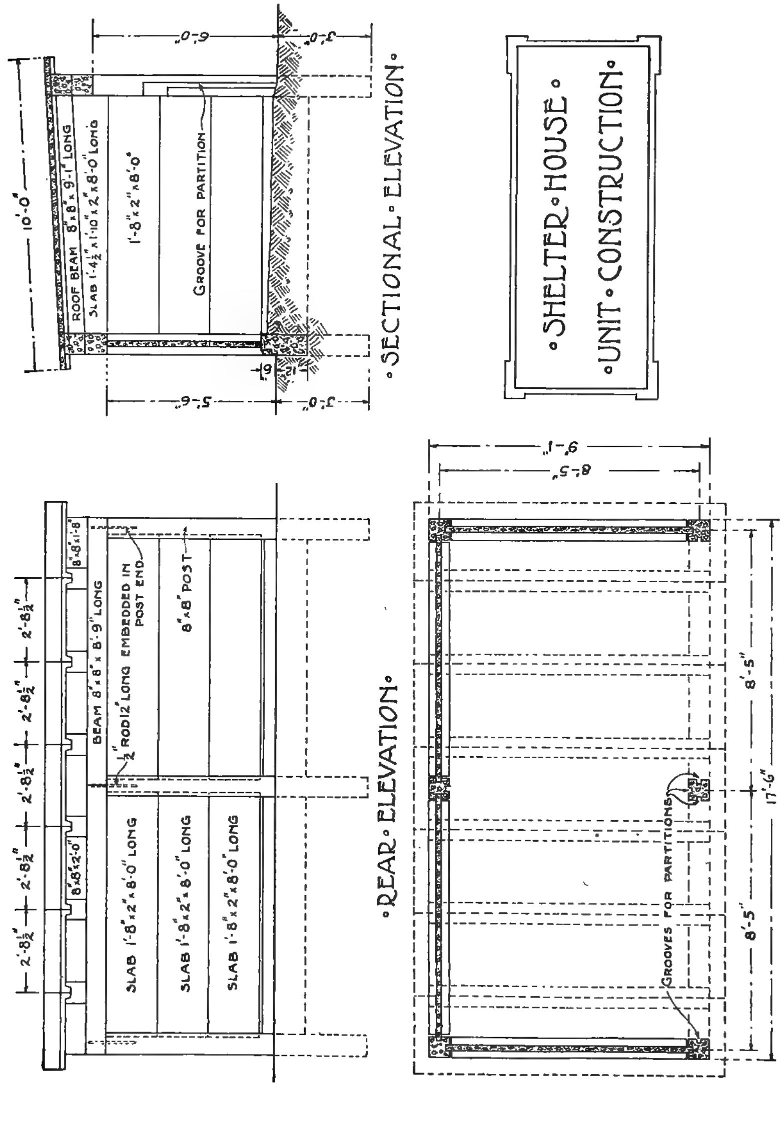


Figure 105. **A Concrete Shelter House of unit construction, cheap and portable.**

desired results are obtained. After removal of the mold, each post or beam should be allowed to cure two or three weeks before using, and during this time should be stored where plenty of moisture can be provided.

The posts may conveniently be hoisted into position with a tripod and tackle, as shown in Figure 44. When placing the posts, care must be taken in securing the proper spacing, alignment and height, as negligence in this regard will cause extra work.

As soon as each post is placed the earth must be well tamped around it to within one foot of the surface. A small quantity of water may be poured in around the posts, as this helps to compact the soil. Excavation should next be made between the posts on the three enclosed sides for a curb, which will be the same width as the posts, extending 6 inches above ground and 12 inches below ground. No curb will be required on the open side of the house unless a floor is to be put in. The forms for the curbing should be put up and filled with concrete of the same mixture as recommended for the posts. The top of the curb must be flush with the ends of the recesses in the posts. Each section of curb 7 feet 9 inches long requires about 2 sacks of cement, 5½ cubic feet of sand and 9 cubic feet of gravel or stone. If a concrete floor is desired, the surface should be 2 inches below the curb line, and the space between the surface of the floor and the top of the curb filled with bedding. If a dirt floor is to be put in, the surface may be made flush with the curb.

Figure 106. Concrete Block Hog House on the farm of Eugene D. Funk, near Shirley, Illinois. This house, which is 42 feet by 24 feet in dimensions, contains 10 pens, a feed room and a store room. The walls were built of 8-inch by 16-inch solid concrete block, 5½ inches thick, and were later finished off with cement stucco. The floors are of concrete. In connection with this house Mr. Funk also has a large concrete feeding floor.

The wall slabs are all 8 feet long and 2 inches in thickness and may be varied in width to fit the space to be filled. They may be conveniently made in the mold shown in Figure 107, using the top form only. These slabs, as well as those for the roof, should be made of a 1:2½:2 mixture. The gravel or stone must be between ¼-inch and ½-inch in size. The width of each slab is 20 inches, with the exception of the upper slabs for the ends of the building, which are 14 inches wide at the back and 20 inches wide at the front. The reinforcing consists of ¼-inch round rods, spaced as indicated on the diagram. The slabs are raised and slipped into the column recesses, with the assistance of the tripod and tackle, and are sealed in place with mortar, this work being done as outlined on pages 48 and 51.

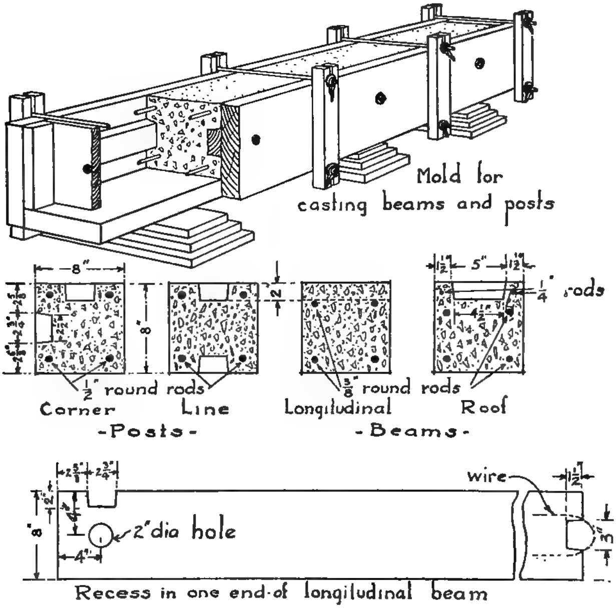


Figure 107. Post and Beam Mold, cross sectional views of posts and beams for slab shelter house, and plan of a longitudinal beam.

By removing the cleats used to provide recesses, the mold required for casting the posts also serves to cast the longitudinal beams. Four of these are required, and the length of each is 8 feet 8 inches. Four ⅜-inch round reinforcing rods are used. Referring to Figure 107, bottom illustration, it will be noticed that the ends of both longitudinal beams are to be recessed on one side at a point 2⅝ inches from one end, this being necessary to provide slots for the upper end slabs. When the house is made more than two sections in length, intermediate longitudinal beams need not be recessed in this way.

The longitudinal beams are held in position by steel pins placed in the top end of the columns and allowed to extend up through holes in the beams. These holes are made by placing wooden plugs in the mold and drilling out the plugs when the beams are ready to be put up.

Where two longitudinal beams adjoin each other, as is the case at the center posts on the front and back, a half-round section is left in the abutting ends of each, so that the steel pin may come up between them. Wire loops placed in these ends, as shown, will aid in holding the beams in place. All beams must be laid in a bed of grout or mortar.

The post mold is also utilized for the purpose of casting the roof beams, which are 10 feet long and 8 inches by 8 inches in section, with a depression in the top side, into which the roof slabs fit. This depression is made by placing in the mold a strip of wood of the required size. The roof beams are reinforced with four 3/8-inch round rods and two 1/4-inch round rods placed as shown in Figure 107.

The 1/4-inch rods should be laced to adjacent 3/8-inch rods with baling wire or similar material, at intervals of 12 inches. Concrete of a 1:2:4 mixture is used. The distance between beams is 2 feet 8½ inches, center to center, and the spacing must be accurate. Between beams at the wall line there is a space of 24½ inches long by 8 inches high, which may be filled either by concrete blocks or by concrete deposited in place, as desired.

The roof slabs (See Figure 109) are made in a mold arranged to provide lugs or flanges on both sides. For the end slabs, piece (b) is moved in 2½ inches, which gives it a bearing on core (a) and produces a lug on only one side, making a slab 2 feet 5½ inches in width. A pallet is necessary for casting these slabs, this being required to hold core (a) in position. The sides and ends of the molds are held tightly to the pallet by steel clamps, which may be made of heavy wagon tires or

Figure 108. Concrete Block Hog House on Henry Hanson's Echo Valley Farm, Odeboldt, Iowa. Comfortable and airy quarters for the porker inevitably lead to increased profits. Mr. Hanson's hog house is pleasing in appearance and moderate in cost.

similar material, so bent as to be 5½ inches in width, with one leg 4 inches long and the other 6 inches long. For casting and roof slabs, the clamps bearing upon the block (b) should be placed with the 6-inch leg up and the 4-inch leg under the pallet, while for other slabs these clamps will be used in the reverse position.

After the roof slabs have been placed upon the beams, the spaces between slabs may be filled with pitch or grout although this is optional and not necessary to make the roof watertight.

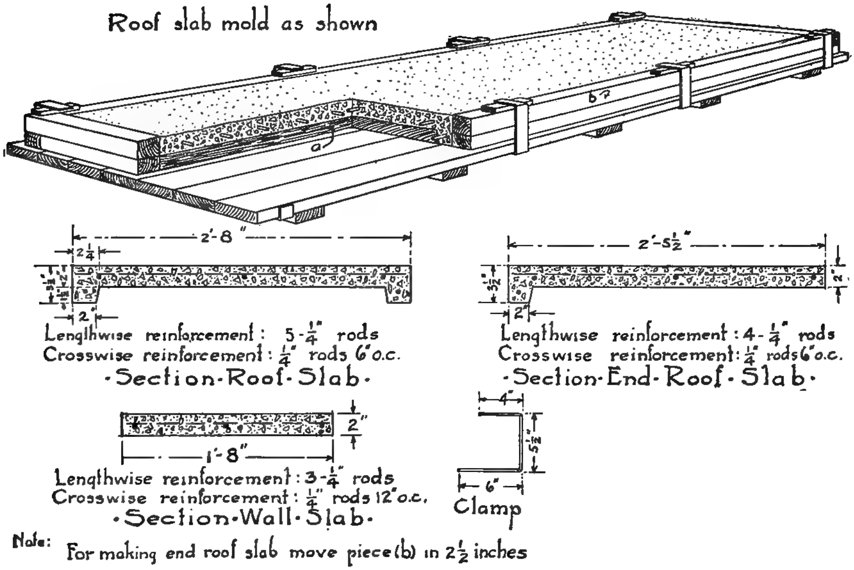


Figure 109. Slab Mold.

Table of Concreting Materials

Members	Mixture	Cu. ft. Concrete	Sacks Cement	Cu. Ft. Sand	Cu. Ft. Gravel or Stone
Posts	1:2:3	24.6	6.5	12.8	18.9
Beams	1:2:4	42.8	9.5	19.3	38.0
Side Slabs	1:2½:2	24.0	6.5	16.6	33.3
Roof Slabs	1:2½:2	32.0	9.0	22.5	17.8
Total	....	123.4	31.5 (8 Bbls.)	71.2	108.04

Cement at $2.00 per bbl.	$15.75
Sand at $1.00 per cu. ft.	2.64
Gravel at $1.00 per cu. yd.	4.00
Total cost of concreting material	$22.39

REINFORCING METAL—BILL OF MATERIALS

12 pcs. ½-inch round rod 18 feet long, 144 lbs. at $1.90 per 100 lbs.	$ 2.74
20 pcs. ⅜-inch round rod 18 feet long, 135 lbs. at $2.05 per 100 lbs.	2.77
72 pcs. ¼-inch round rod 18 feet long, 216 lbs. at $2.30 per 100 lbs.	4.97
Total cost of reinforcing metal	$10.48

THE above bill of materials is based upon the economical use of the rods. The prices given are quite generally quoted by steel manufacturers in the central states.

The forms for the various members are simple to construct, and if attention is paid to the designs shown in Figures 107 and 109, no further instructions should be necessary. 2-inch dressed lumber is best for use in all parts of the forms except the pallets or bottom boards, which may be made of lighter material if properly supported.

If it is desired to build this house with monolithic concrete, blocks or cement plaster, instead of separately molded members, the slab roof may be used in any case with satisfactory results. For a monolithic block or cement plaster house the foundation walls should be 6 inches in width and deep enough to extend below the frost line, the work being done in accordance with instructions given in the chapter on "Foundations." If the walls are to be of monolithic construction they may be continued up on three sides to a point 5 feet above the foundation, leaving the fourth side open. A reinforced column, 5 feet in length, previously cast in the mold box shown in Figure 107, is then placed in position on the open side of the building, midway along the foundations. Longitudinal beams of the same type and dimensions as those used in the unit construction are then placed in position. The roof beams are next put on as heretofore described and the side walls built up flush with the tops of the roof columns. As soon as the walls are sufficiently hardened the structure is ready for the roof slabs.

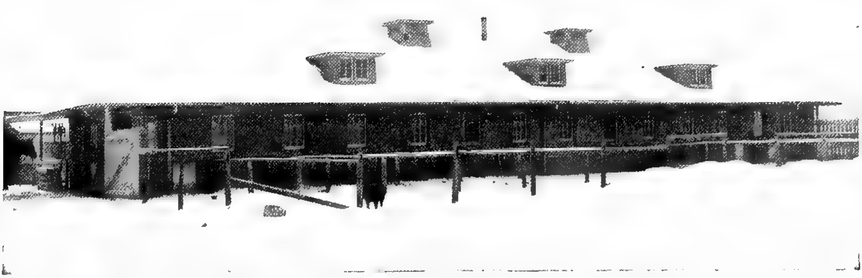


Figure 110. **An Iowa Hog House equipped with steam heat, King System of ventilating and litter carrier system.**

To construct the house of concrete blocks, the foundation is laid as before, care being taken to level off the top. The walls should be laid as directed in the chapter on "Concrete Block Walls." The beams used over the openings may be the same as those used for the hog house of unit construction, the same being true of the roof beams. After the latter are in place, the side walls are continued up level with the lower end of the roof beams, and the spaces between these beams are filled in with blocks or monolithic concrete. The end walls are also continued up of monolithic concrete until flush with the tops of the roof beams, which are placed in the usual manner. This house will require about 220 standard 8x8x16-inch blocks and 22 8x8x8-inch half blocks, if built to a height of 5 feet 4 inches between the lower end of the roof and the ground. If it is desired to construct the house with cement plaster walls, the posts, curbs, beams and roof should be erected as for the unit house. Metal lath is then stretched around the structure and wired to the posts and beams at close enough intervals to make it rigid. Plaster coats should be applied to the metal lath as described on page 52.

Figure 111. Interior of Concrete Milk House and Creamery, Iowana Farm, Davenport, Iowa. In a concrete structure absolute cleanliness can be maintained at all times, with a minimum amount of work.

A Five-Pen Hog House of Concrete Blocks

THIS house is designed to shelter a small number of sows with winter litters. It has concrete block walls, and a reinforced concrete roof, supported by concrete columns and ridge beams. The concrete floor has provision for drainage, and the ventilation system supplies plenty of fresh air without compelling the hogs to lie in a draft. Before farrowing time the floor of the pen where the sow makes her nest should be covered with a mat made of 2 x 4's with a liberal supply of bedding placed upon them. These mats may be removed when the pigs are a few weeks old.

Directions for putting in the foundations for the building will be found on pages 15 to 21. The wall blocks, as well as the concrete window sills and lintels, may be purchased from the nearest dealer, or made on the place with equipment described on pages 45 and 47. The window and door framing is simple and can be executed by anyone with a little experience in carpentry.

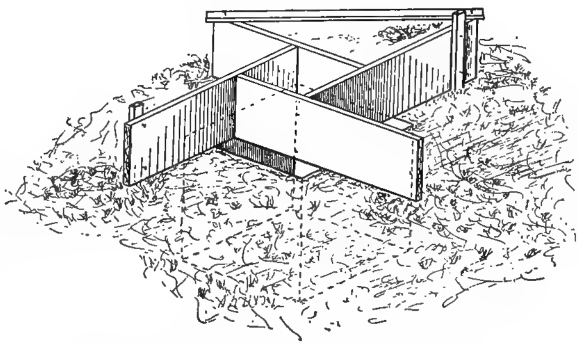


Figure 112. Simple Box Mold for Column Footing.

The piers or footings for the support of the center columns are put in at the same time as the wall foundation, box forms, like that shown in Figure 112, being used. The four ⅜-inch reinforcing rods for the columns must be securely embedded in the piers, care being taken to space the the rods properly. After the piers have become hard enough to support the weight of the columns, forms for the latter (See Figure 122) are erected and filled with concrete wet enough to be quaky. The tops of the columns should be left squared off with reinforcing rods protruding about 8 inches. These will later be embedded in the ridge beam above.

The ridge beam and roof should be cast together as a monolith, using forms similar to that shown in Figure 131. Simple box forms, supported by light scaffolding, will suffice for the eaves. The reinforcing rods in the ridge beam should be placed 1¼ inches above the bottom of the beam and wired to the column reinforcing. The stirrups, which consist of ⅜-inch rods bent into U-shape, are 12 inches high. They are placed in pairs, 6 inches to either side of each column and 12 inches apart, as shown in the section and elevation of the beam, in Figure 114. Two additional ½-inch reinforcing rods 4 feet long, are put in above each column, about 1¼ inches below the top of the beam.

The concrete for the roof should be mixed wet enough to be mushy, and the entire roof should be placed at one operation if practicable. Should it be impossible to do the work continuously, the sections must be joined together as directed on page 58, (chapter on roofs) making

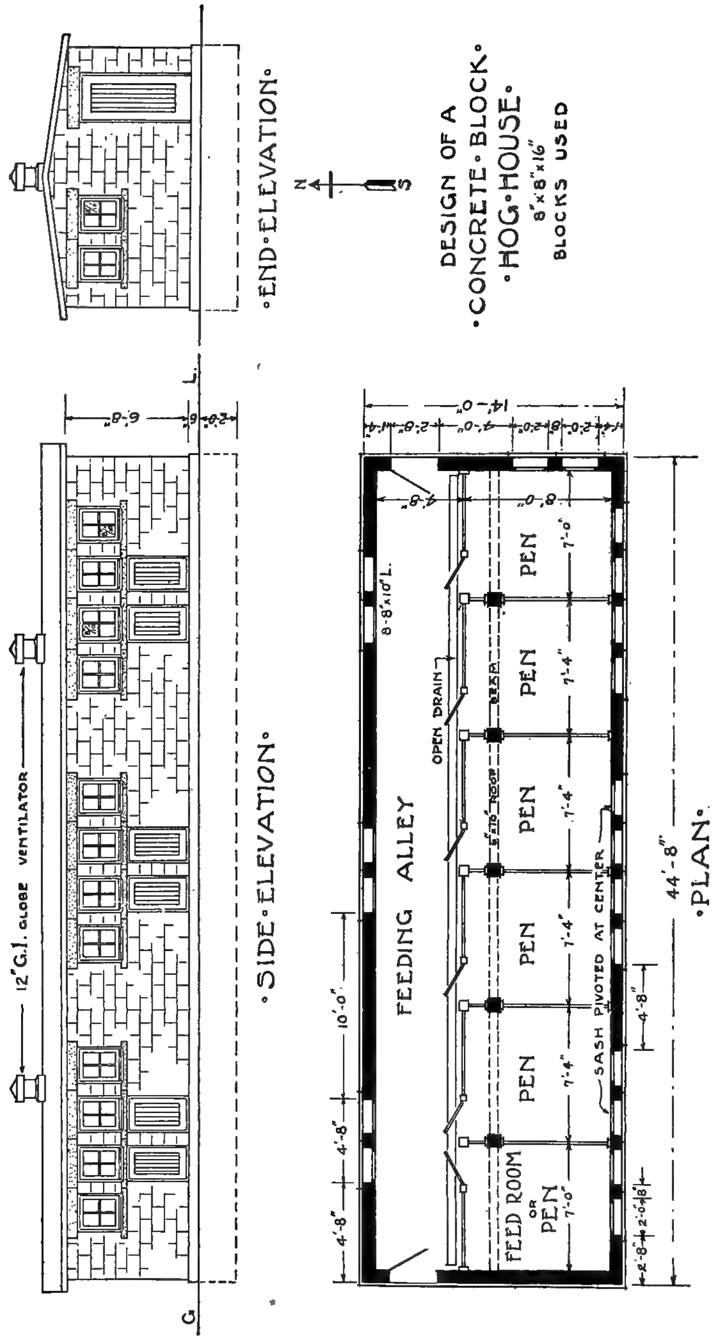


Figure 113. A Fine Pen Hog House of Concrete Block. Many hog raisers use houses of this type for early farrowing, housing later litters in less substantial structures.

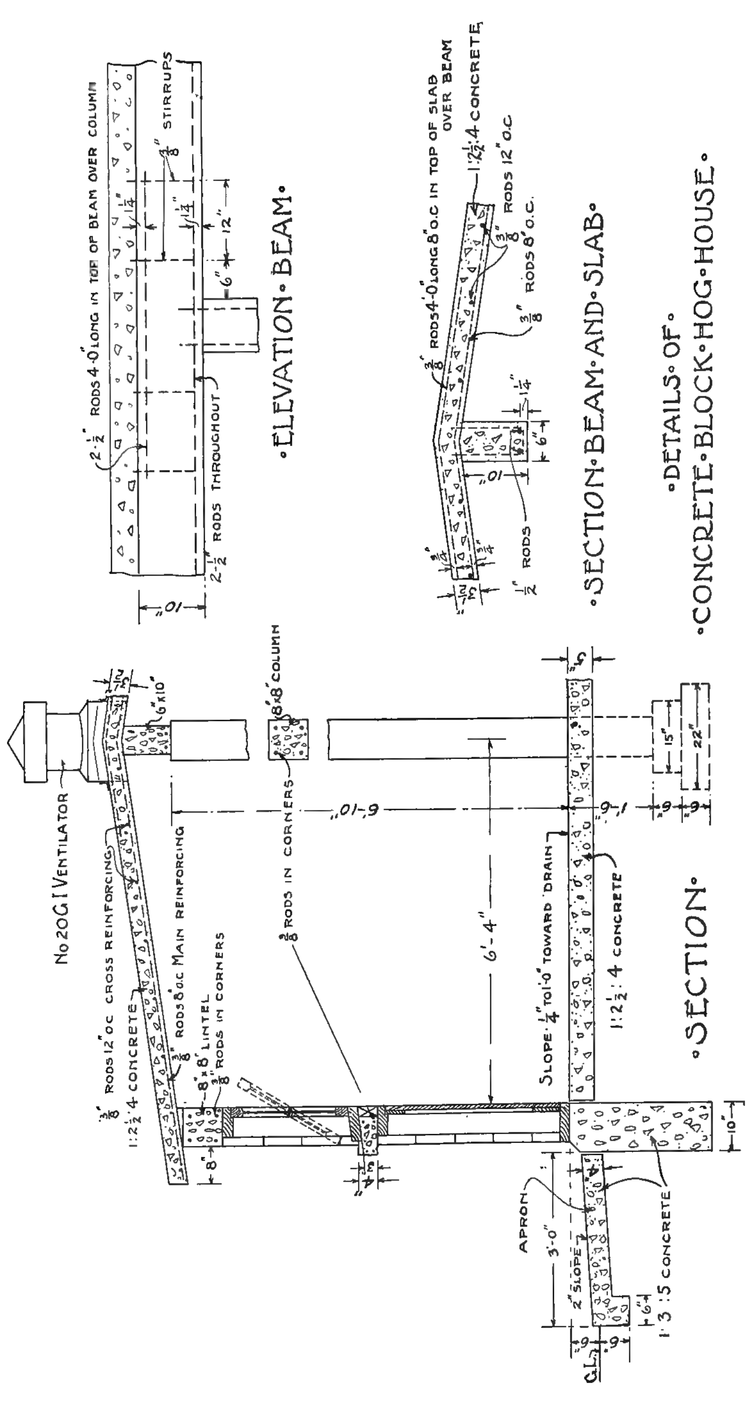


Figure 114. **Detailed Sectional Views, Five Pen Hog House of Concrete Blocks.**

all joints run from ridge to eave, and never in any other direction. A mixture of 1:2:4 should be used for the ridge beam and body of the roof should be mixed in the proportions of 1:2:3. The roof should be finished off in the same manner as a sidewalk and protected against sun, wind and frost for two weeks by covering with wet straw, weighted down to keep it in place. The forms must be left in place until the roof is thoroughly hardened and all doubts as to the strength of the work removed.

Proportions (See page 157).

Foundations and apron, Specification D.

Floor, sills and lintels, and roof slab, Specification A.

Columns and beams and roof slab, Specification B.

Body of concrete blocks, Specification C.

Mortar Facing for blocks and for laying blocks, 1:2 cement and sand.

Table of Materials

	VOL. Cu.Yds	MIX-TURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Foundations	9.45	1:3:5	43.9	4.91	132.7	8.13	219.4
Apron	5.40	1:3:5	25.1	2.81	75.8	4.64	125.4
Concrete Blocks { Body	......	1:2½:4	47.7	4.34	117.2	6.98	188.4
Concrete Blocks { Surface	......	1:2	12.5	.70	19.0	......	.....
Sills and Lintels	......	1:2:3	10.7	.82	22.1	1.17	31.6
Columns	.70	1:2:4	4.2	.32	8.5	.62	16.5
Roof Beams	.70	1:2:4	4.2	.32	8.5	.62	16.5
Roof	6.80	1:2:3	47.3	3.54	95.5	5.24	141.4
Floor	8.50	1:2:3	59.2	4.42	119.3	6.55	176.7
Total	....	......	254.8 (63¾ Bls)	22.18	598.6	33.95	915.9

Allowing for a sufficient quantity of 1:2 cement and sand mortar, the total concreting materials necessary will be about 67 barrels of cement, 23.5 cubic yards of sand and 34 cubic yards of screened gravel or crushed stone.

Figure 115. Concrete Hog House on Barber Estate, Barberton, Ohio.

Approximate amount of Reinforcing required:

Crosswise Reinforcing in Roof,	68	⅜-inch rods 16 feet long	Weight 408 Lbs.
Lengthwise Reinforcing in Roof,	48	⅜-inch rods 16 feet long	Weight 288 Lbs.
Column Reinforcing,	20	⅜-inch rods 12 feet long	Weight 90 Lbs.
Ridge Beam Reinforcing,	6	½-inch rods 16 feet long	Weight 64 Lbs.
Stirrups,	6	½-inch rods 12 feet long	Weight 48 Lbs.
		Total	898 Lbs.

(Order about 10 per cent extra to allow for waste.)

Concrete Blocks, Sills and Lintels

20	corner blocks	8″x8″x16″
485	wall blocks	8″x8″x16″
19	¾ wall blocks	8″x8″x12″
113	½ wall blocks	8″x8″x 8″
16	¼ wall blocks	8″x8″x 4″
13	special blocks, 4″ high, 8″ long, 8″ thick, to fit around window sills.	
20	sills	32″ long, 4″ high, 10″ thick
20	lintels	32″ long, 8″ high, 8″ thick
2	lintels	40″ long, 8″ high, 8″ thick

IF it is desired to build the house with monolithic concrete walls, the work may be carried on in the same manner as for the larger structure described on pages 137 to 140 of this booklet. The walls should be 8 inches in thickness, made of a mixture of 1 sack of Portland cement to 2½ cubic feet coarse sand, to 5 cubic feet screened gravel or crushed stone. If these proportions do not give as smooth surfaces as desired, the amount of stone should be decreased until a 1:2½:4 mixture is obtained. Sufficient reinforcing must be placed around the window and door openings. The following materials will be needed to build monolithic walls for this structure: 16.5 barrels of cement, 6 cubic yards of sand and 12 cubic yards of stone. A good description of the forms required for this work will be found in the chapter on "Monolithic Walls," pages 32 to 44.

Figure 116. Concrete Block Calf and Hog House on farm of C. S. McNett, Cary, Illinois. Built by the owner.

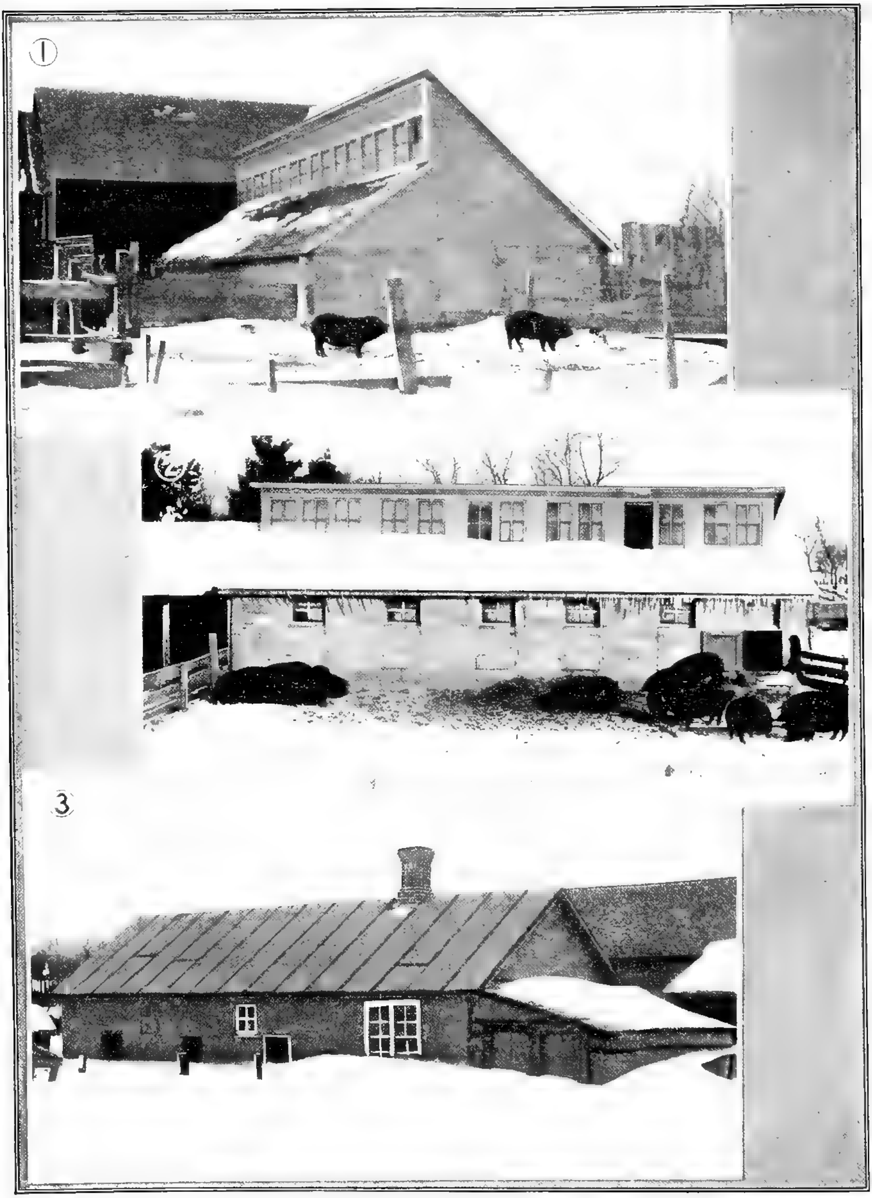


Figure 117. WINTER HOG HOUSE SCENES

(1) Jacob Brinkman's Hog House, Early, Iowa. Dimensions, 22 feet by 40 feet. Cost, $300.

(2) P. Schaller's Hog House, Early, Iowa. Dimensions, 18 feet by 36 feet. Cost, $300.

(3) K. J. Ammentorp's Hog House, Withree, Wisconsin. Dimensions, 35 feet by 9 feet. Cost, $160.

A Five-Pen Cement Plaster Hog House

THE unit-frame, plaster-wall hog house shown in Figure 118 is designed to meet practically the same requirements as the one described on the pages immediately preceding, varying widely from the latter, however, in the method of construction. The walls are cement stucco applied to metal lath, which is supported upon a frame of reinforced concrete columns and beams, and stiffened by vertical and horizontal reinforcing rods.

In constructing the house, the procedure should be about as follows: The necessary columns and beams are first cast in mold boxes similar to those shown in Figure 107, of a mixture of 1 sack Portland cement to 2 cubic feet of clean, coarse sand, to 4 cubic feet screened gravel or crushed stone. The required number of columns and beams, their sizes and amount of reinforcing metal in each, is given in the following table. Reinforcing rods should be placed 1½ inches in from each corner, but need not be wired together in the manner heretofore described. Two of the reinforcing rods on corners diagonally opposite should be allowed to project 3 inches from the bottom of the column; this may be accomplished by boring holes in the ends of the molds and allowing the rods to project through. When the columns are set up these rods will be grouted into holes drilled into the foundation wall. Small pieces of fence wire should be placed in the sides of the columns which are to face out, these being used later to secure reinforcing rods and metal lath. These wires should be placed in the columns 12 inches apart.

The columns and beams should be given an opportunity to thoroughly harden and acquire strength before being placed in position, and during this period the foundation and center column footings should be put in. This foundation should be 12 inches wide and 2 feet 6 inches deep, while the footings or piers should be 1 foot 6 inches square for the first 6 inches, and 12 inches square for the 2 feet above, as shown in the sectional view of the house.

When the tops of the foundations and piers are being leveled off, two 2-inch holes, 3½ inches deep, should be left at intervals of 7 feet along the foundation, and also on the top of each pier. These holes may be made by inserting in the work galvanized iron tubes, which are easily withdrawn later. They must be correctly spaced, of course, to receive the protruding reinforcing rods from the columns. Just before the columns are placed in position, the holes are filled with grout of a creamy consistency. The columns are then placed, and the reinforcing rods forced down through the grout, which soon hardens, giving a good bond.

The roof beams are next erected in the same manner as for the unit shelter house (see page 119). The monolithic slab roof is 3½ inches thick. The roof forms may be erected the same as those for the concrete block house. The reinforcing consists of ⅜-inch rods spaced 12 inches apart, lengthwise, and 7 inches apart crosswise, placed ¾-inch above the bottom of the roof. Additional reinforcing, consisting of ⅜-inch rods, 3 feet long, spaced 7 inches apart, should be put in astride

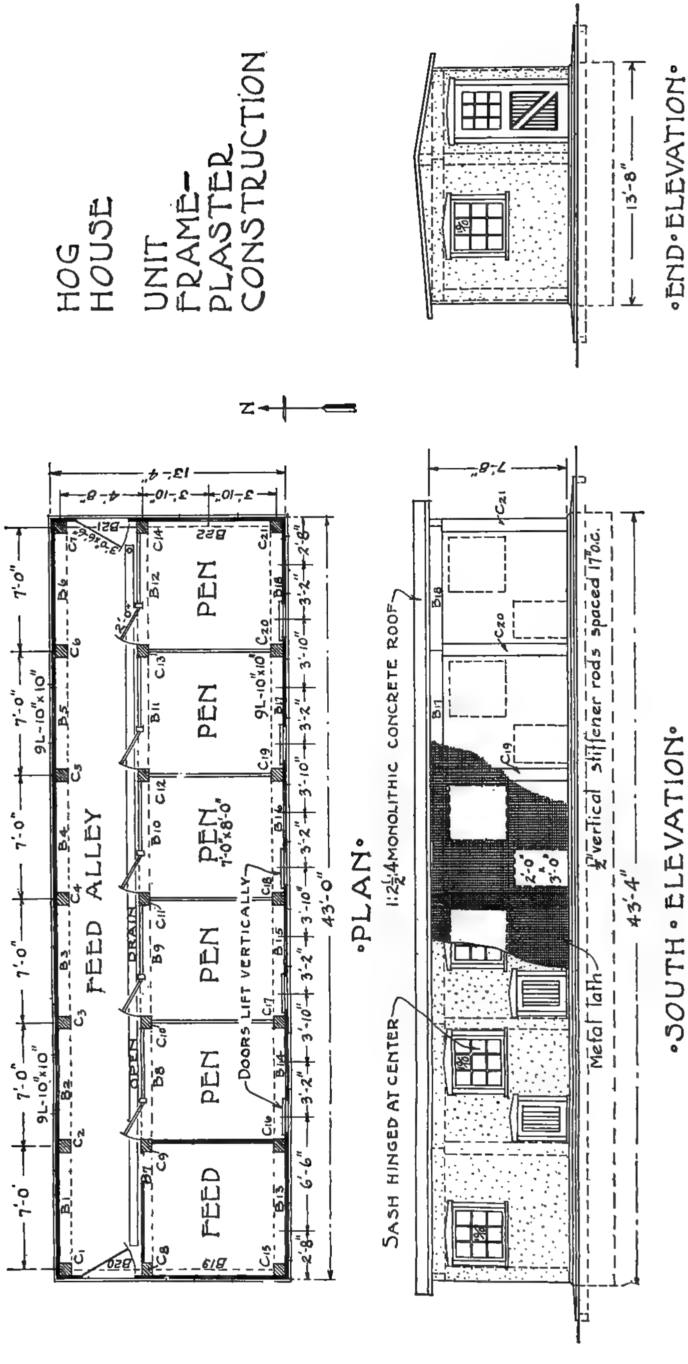
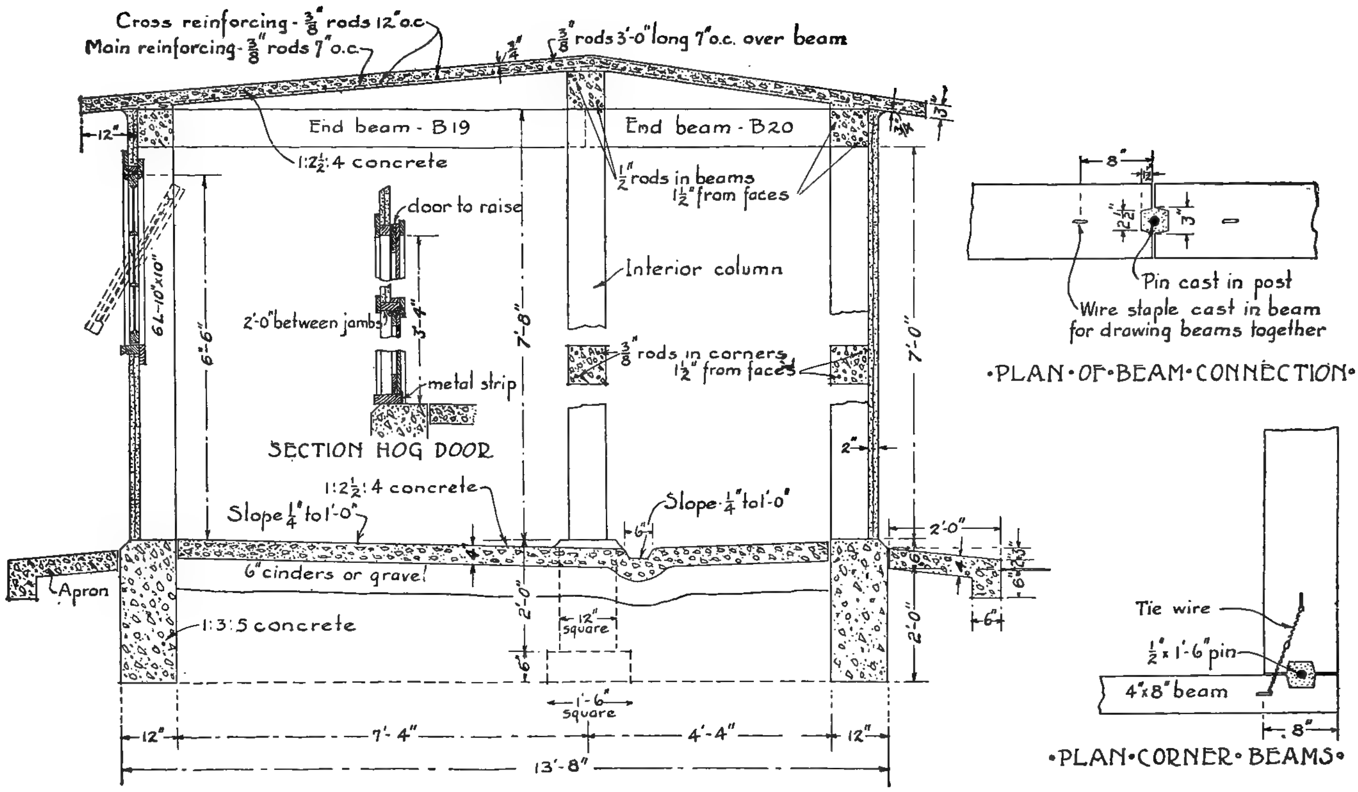


Figure 118. **Plan and Elevation of a Cement Plaster Hog House with Reinforced Concrete Frame.**



•SECTION•

Figure 119. **Detailed Sectional Views of Cement Plaster Hog House. The arrangement of columns and beams is clearly shown in this illustration.**

of the ridge, as shown, one inch below the surface. The work must be surfaced with a steel trowel, and if difficulty is found in obtaining a smooth finish, a small amount of 1:2 mortar may be added. The roof must be protected from sun, wind and freezing, as heretofore described.

To the outside of the reinforced concrete frame ½-inch vertical reinforcing rods are wired at intervals of not more than 18 inches, so spaced that vertical reinforcing will fall 2 inches to each side of all window and door openings. If desired, the lower ends of these rods may be grouted into holes drilled in the top of the foundation. Only one horizontal reinforcing rod is required, this being a ½-inch rod, placed 3 feet 3 inches above the top of the foundation. The horizontal rod is wired to the vertical rods at each intersection.

Wire lath (described on page 53) may be obtained in convenient widths, and will be found a suitable material to receive the cement plaster. It should be wired to the reinforcing rods at intervals sufficient to hold it perfectly rigid, special care being taken to wire all laps so that both sections of the lath will act as a unit. Lath should be wired at intervals of not over 12 inches. The cement plaster coats should be applied according to the directions given on pages 52 to 57. If the frame is not sufficiently rigid to hold the first coat readily, temporary wood bracing should be put up. This may be removed as soon as the first coat is hard. Three coats should be applied to the outside of the wall, and one coat to the inside. The metal lath should be entirely encased in cement plaster, as exposed portions are subject to rust, which in the course of a short time causes the wall to be weakened materially.

Proportions (See page 157).
Foundations and apron, Specification D.
Roof and floor, Specification C.
Columns and beams, Specification B.
Plaster Walls, 1:2 cement and sand mortar.

Table of Materials

	VOL. Cu.Yds	MIX-TURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Foundations and Footings.......	10.80	1:3:5	50.1	5.62	151.2	9.29	250.6
Apron........................	3.70	1:3:5	17.2	1.72	46.4	3.18	85.8
Columns and Beams............	4.77	1:2:4	28.8	2.15	58.0	4.25	115.0
Plaster Walls *................	......	1:2	56.5	4.15	112.1	......	.....
Roof..........................	6.25	1:2:3	43.5	3.25	87.8	4.81	129.9
Floor.........................	6.50	1:2:3	45.2	3.38	91.3	5.01	135.1
Total..............	....	.....	241.3 (60½ Bls)	20.27	546.8	26.54	716.4

*Based on 1:2 cement plaster walls 2 inches thick, making no allowance for waste. At least 15 per cent additional material is generally required for the walls to take care of waste. See Table E, page 54.

A Large Reinforced Concrete Piggery

MUCH has been said of late both in favor of and in opposition to the centralized hog house. The large piggery has unquestioned advantages in the way of facilitating feeding and cleaning, as well as providing opportunity for use of artificial heat for winter farrowing and affording a good place to fatten pigs for market. On the other hand, the objection has been raised that with the centralized hog house, as ordinarily constructed of wood, there is greater danger from disease. However, with a concrete building all danger will be removed if ordinary care is taken and the house properly disinfected from time to time.

Figure 120 shows the ground plan and elevation, and Figure 121 the details of a large monolithic piggery having 24 ordinary pens, 1 special pen and a feed room. The walls are of monolithic concrete reinforced as directed on pages 39 to 44. (See elevation views, Figure 120.) The roof is of reinforced beam and panel construction, with windows set at proper angle to throw the sunlight down into the pens on the north side of the house during February, when it is most desired for early litters. The roof panels are supported by 8 x 15-inch beams placed on 7-foot 4-inch centers, these beams resting upon 8 x 8-inch columns. The floor is laid upon a sub-base of well tamped gravel or cinders, and is given a slope of ¼-inch to the foot toward the drains, which are conveniently located to either side of the passageway.

The excavating for foundations and column footings, buildings of the forms and placing of the concrete may be carried on according to directions furnished in the chapter on "Foundations." The foundations have a width of 10 inches and a depth of 3 feet below the bottom of the hog doors. As soon as they have become sufficiently strong, the wall forms should be erected according to the directions given on pages 33 to 35.

Fifteen inches below the top of the inside of the wall, recesses 4 inches in depth, 8 inches wide and 15 inches high must be left for the roof beams. These recesses must be accurately spaced, so that they will be exactly opposite the corresponding columns. The recesses may be easily made by means of small core boxes.

For a house of this size it is advisable to build forms enough for but three or four columns and a like number of roof beams, unless the owner or the contractor will be able to make use of the additional lumber later. As soon as the walls are up, the columns, beams, and roof should be put up according to the following procedure: Forms similar to those shown in Figure 122, diagram A, should be erected for four columns and four roof beams. The columns should then be poured up to the under side of the lower roof beams. The reinforcing should be put in as directed in the description on page 39 and illustrated in Figure 35. As soon as the forms may safely be removed the next four columns are cast in a similar manner, this work continuing until these members are all in place.

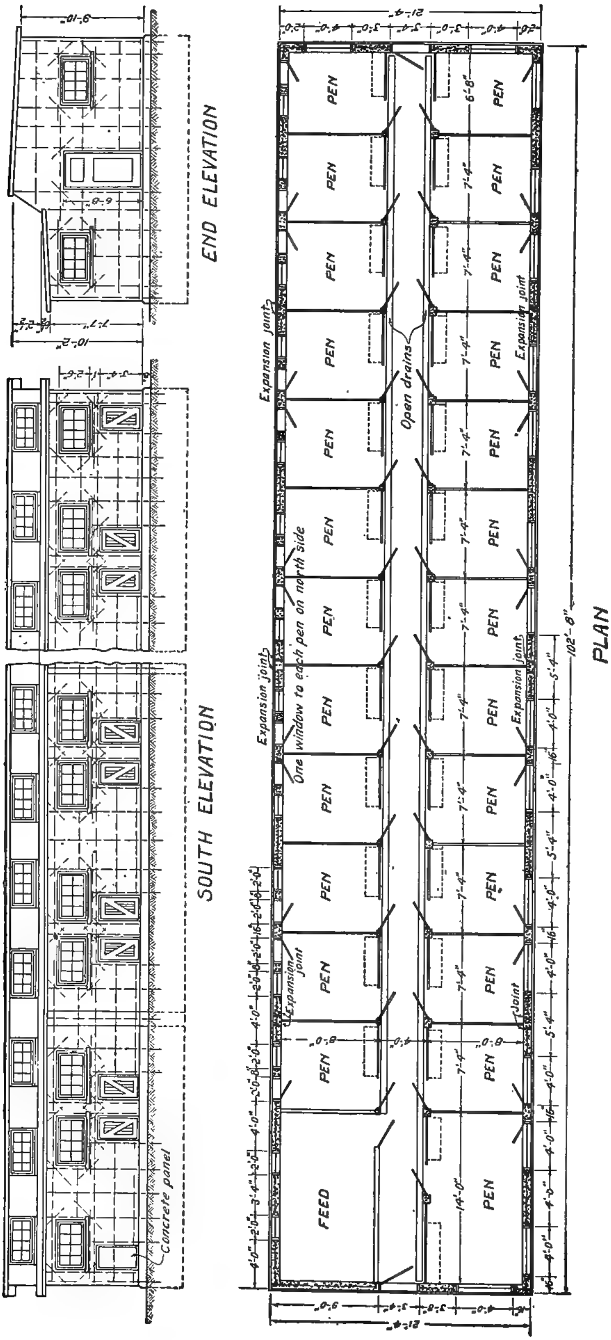


Figure 120. Plan of a Reinforced Concrete Hog House, having 25 Pens and a Feed Room. When desired, concrete blocks may be substituted for monolithic walls, all of the dimensions being convenient for block construction.

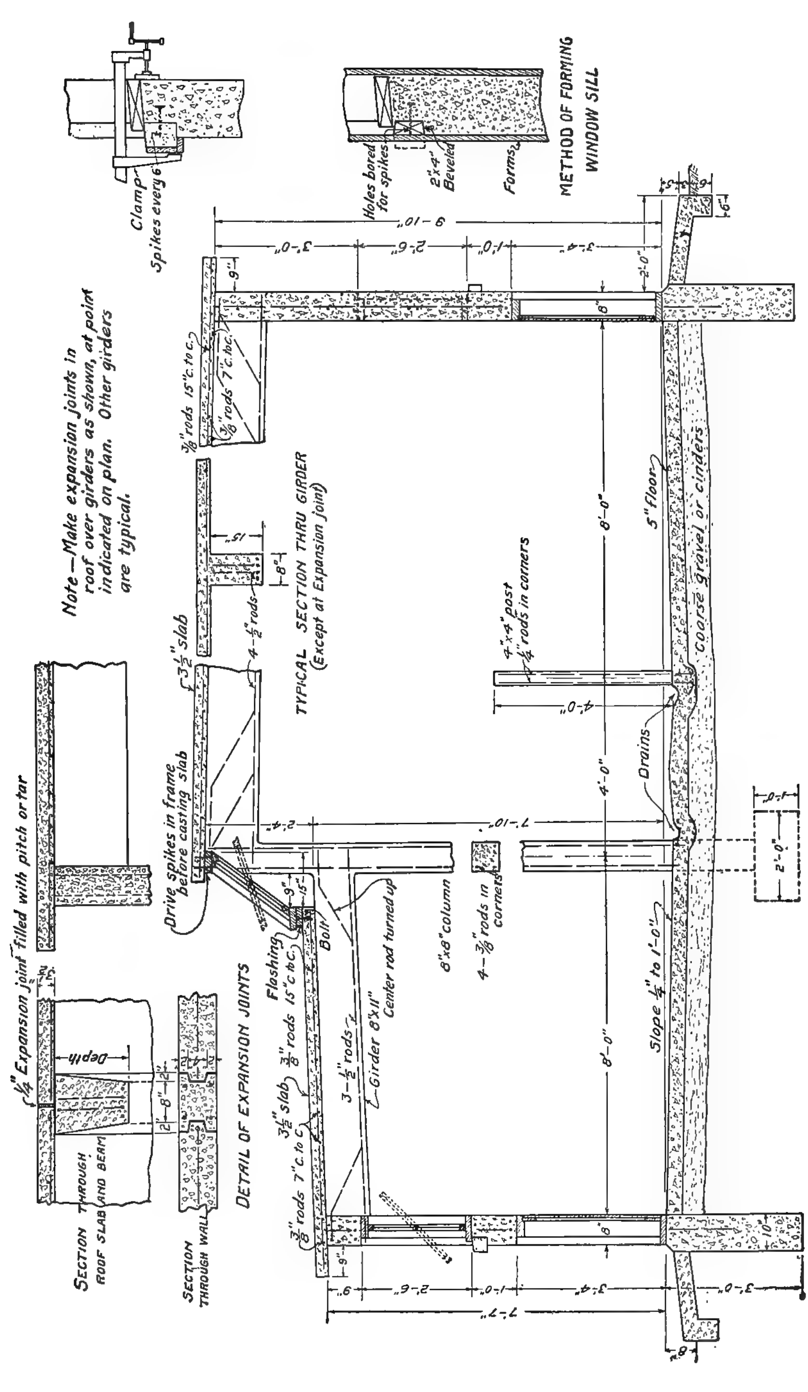


Figure 121. Sectional Details of Reinforced Concrete Hog House. The roof windows are set at an angle for the purpose of throwing the sun's rays upon the floor of the north pens during February and March.

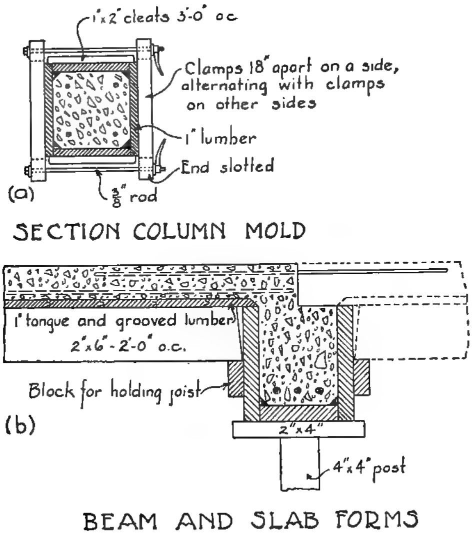


Figure 122. Sectional Views of Molds for Monolithic Columns, Roof Beams and the Roof Proper; the lower diagram shows the method of temporarily discontinuing roof work over beams.

Forms for the roof beams and slabs and that portion of the columns above the lower beams, are then put up for a distance sufficient to include four panels. The beam molds are next filled and the roof is concreted to a depth of 3½ inches. When temporarily discontinuing work, concreting should be stopped directly over a beam, in the manner shown in Figure 122, Diagram (b). The reinforcing should not be severed at the point where concreting is left off. Before resuming work the concrete previously placed should be thoroughly cleaned, moistened and painted with grout.

Proportions (See page 157). Foundations, column footings and apron, Specification D. Walls, Specification C. Columns and roof beams, Specification B. Sills and lintels, floor, posts and roof slabs, Specification A.

Table of Materials

	VOL. Cu.Yds	MIX-TURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Foundations	15.12	1:3:5	70.2	7.86	212.3	13.00	351.1
Column Footings	2.36	1:3:5	11.0	1.23	33.1	2.03	54.8
Apron	7.03	1:3:5	32.6	3.66	98.7	6.05	163.2
Walls	40.58	1:2½:4	245.4	18.22	492.5	36.10	975.0
Floor	31.25	1:2:3	217.5	16.25	438.8	24.06	649.8
Columns	1.92	1:2:4	11.6	0.86	23.2	1.71	46.4
Posts	0.20	1:2:3	1.4	0.10	2.8	0.15	4.2
Roof Beams	7.22	1:2:4	43.6	3.24	87.6	6.42	173.2
North Roof Slab	15.75	1:2:3	109.6	8.19	221.1	12.13	327.4
South Roof Slab	9.38	1:2:3	65.3	4.88	131.7	7.22	195.0
Window Sills	0.40	1:2:3	2.6	0.18	4.9	0.36	9.8
Total	...	...	810.8 (202¾ Bbls)	64.67	1747.7	109.23	2949.9

Approximate amount of Reinforcing Metal required:

5500 feet ½-inch round rods. .... Weight 4700 Lbs.
6800 feet ⅜-inch round rods.................... Weight 2550 Lbs.
250 feet ¼-inch round rods.................... Weight 50 Lbs.
Total.................................. 7300 Lbs.

(Add about 10 per cent to allow for waste in cutting.)

Interior Fittings for Hog Houses

Floors. Concrete hog house floors must be built in such a manner that they can be easily cleaned, and the surface must be rough enough to prevent the animals from slipping. The floor should be rounded up to walls, so as to eliminate all square corners, where dirt usually collects. Make the floor slope toward a central drain, avoiding dips and hollows which hold the water and prevent the floor from drying off rapidly after cleaning. (See chapter on Floors, page 23.) The floors of farrowing pens should be covered with removable board mats, made of 2x4-inch timbers, spaced about ⅜-inch apart. These mats need only to cover the corner of the pen where the sow lies down, and should not be nailed or fastened in any way that will prevent removal for cleaning.

Drainage. The hog house floors should frequently be flushed to keep them sanitary. Drainage must be taken care of either by covered conduits or open gutters draining into a cesspool. A sectional view of a gutter and template for making it are shown in Figure 123. If a conduit is preferred it may be placed either in the center or at the side of the passageway and the floor made to slope toward it. It should be wide enough to admit a shovel for cleaning out, and the depth should vary, giving it a slope of ¼-inch to the foot toward the cesspool. Conduits should be covered with reinforced concrete slabs.

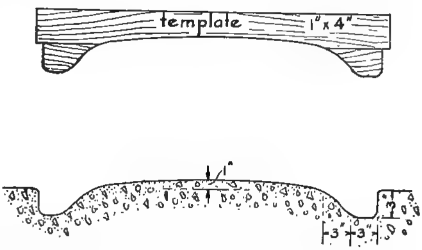


Figure 123. Type of open drain and template for forming the gutter.

Gutters will be found satisfactory if made in about the shape shown and approximately the dimensions given in the figure. Houses with a single row of pens will require one gutter placed in the floor of the passageway on the side adjacent to the pens, while for houses with double rows, a gutter on each side of the passageway will be necessary. A uniform shape will be obtained if the work is finished off with a wooden template similar to that shown in the illustration.

Pens. The pens are conveniently made nearly square in shape, and should have partitions, doors and gates arranged to provide one corner free from drafts, where the sow can make her nest. The feed trough will be conveniently placed along the side parallel to the passageway, and the partition on that side of the pen should be made to swing on hinges, as shown in Figure 126. This arrangement makes it possible to keep the pigs out of the trough while the feed is being put in, greatly simplifying the work.

Partitions. The partitions may be of concrete or of wood. Wire fences are undesirable, because they allow sows in adjoining pens to worry each other, often making trouble at farrowing time. Concrete partitions of unit, monolithic, block or plaster construction have been

used with success and are recommended as preferable to wood. Unit construction should be selected wherever there is an advantage of making the partitions portable.

An ideal partition for monolithic, cement plaster or concrete block structures may be made of reinforced concrete slabs 2 inches thick, 12 inches in width and of convenient length to fit the space to be filled. These may be slipped into slots made of 3-inch, 4-pound channel iron, fastened to the walls and columns by countersunk screws secured to wooden blocks or expansion bolts placed in the wall when the latter are put up.

In the case of monolithic structures, concrete slab partitions may be constructed without the use of channel iron by casting vertical slots in the walls and posts. The slots should extend up 3 feet 6 inches from the floor line, and the top 8 inches should be deep enough to allow the slab to slip in or out. These should be provided in the same manner as for the small unit shelter house described elsewhere in this booklet. The illustration, Figure 125, indicates the methods of fastening channel bars to the wall, and of casting the slots or recesses in walls and columns.

Fenders. To prevent the young pigs from being crushed by the sows during the first few weeks, fenders, or guard rails, should be provided for at least three sides of all brood pens. These fenders must be 8 to 10 inches above the floor and extend out about 8 inches from the wall.

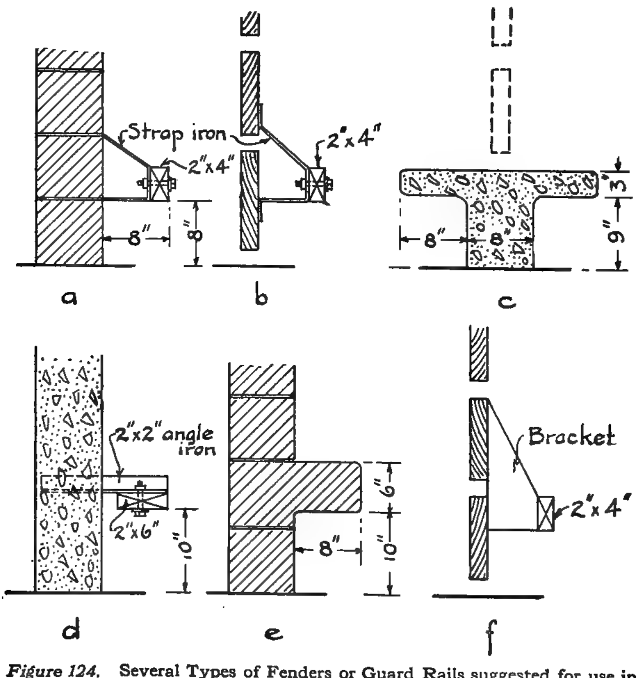


Figure 124. Several Types of Fenders or Guard Rails suggested for use in concrete hog houses.

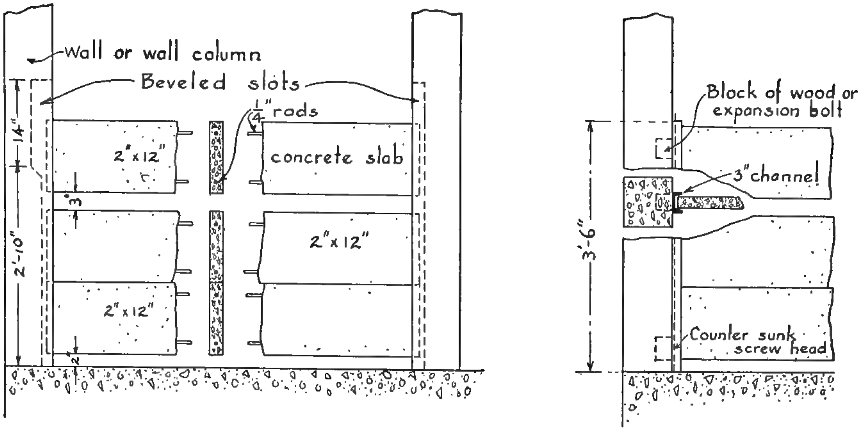


Figure 125. Concrete Slab Partition, made of 2 by 12-inch slabs, which fit into slots cast in the walls, or 3-inch channel iron screwed to wood blocks or wall plugs.

They must be heavy enough to support the weight of the sow, and should have no sharp corners. Figure 124 shows six types of fenders and fender hangers which can easily be adapted to average requirements. Sketch A shows a fender made of two-by-fours with strap iron hangers, suitable for use with block walls; sketch E shows the use of specially shaped fender blocks laid in block walls; C shows a double fender block to be used below concrete slab or plank partitions, and D a fender with angle iron hanger for monolithic walls; B and F show two-by-four fenders with strap iron and wooden bracket supports.

Gates. In hog houses having a row of pens on each side of the passage, there is an advantage in hanging pen gates directly opposite each other. If this be done, any pair of opposite gates may be swung back until they meet or overlap, and then fastened to act as a barrier when the animals are being moved from one pen to another. If the gates are hung 6 inches above the floor, young pigs will be able to get into the passage for exercise. Boards of proper size may be made to slip into slots below the gates to be used when it is desired to keep the pigs within the pens.

Troughs. The troughs for a concrete hog house should always be of concrete. Steel or iron quickly rusts and leaks; wood absorbs the moisture, becomes sour and rots. Forms for concrete troughs are easy to build, and can be made of odd ends of lumber at no additional expense. The trough shown in Figure 126 will be satisfactory for use in any of the hog houses here described, being of convenient size and having a capacity of about 2½ gallons.

A form for casting a trough upside down, using an earth core, is shown in sketch B, Figure 127. On a concrete floor, or after leveling off a plat of ground somewhat larger than the proposed trough, build up the core, approximately to shape, out of plastic earth or clay, using the template as a gauge. The bottomless box can then be placed. If on the ground, stakes should be driven about the form to insure it against

movement in any direction; if on a concrete floor, the box may be held in position with weights, or by braces secured to some nearby object. The core is then worked up to the exact shape desired by using the form as a guide for the template. In this manner uniform thickness is insured on each side. The height of the core will be equal to the depth of the trough, and the height of the template will be equal to the height of the trough. Considerable care must be exercised in working around the earth core, to see that it is not damaged. A shield should be provided to prevent the fresh concrete from knocking off pieces of the core, thus producing an irregular inner surface.

The trough shown in sketch D is similar in construction to that shown at "B" with the exception that a wooden core is substituted for the one of earth and the casting is done on a wooden pallet instead of on the ground.

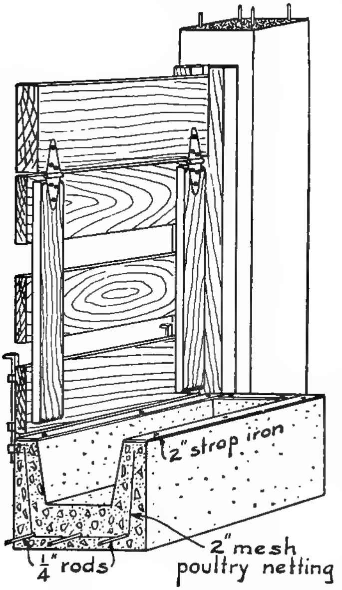


Figure 126. Concrete Trough and Trough Gate to prevent hogs from getting to trough while the slop is being put in. For the houses described in this booklet, troughs should be 12 inches wide, 10 inches high and 4 feet long, with a depth of 6 inches.

The trough shown in sketch "E" can readily be cast on a wooden pallet or in place such as on a solid foundation or a concrete floor. In the latter two cases the wooden pallet will be omitted.

After the reinforcing and concrete for the base of the trough has been placed, the remaining concrete must be worked into place with a trowel and struck off with the template. A mortar top is then placed with the trowel and finished to a smooth surface.

The reinforcing for troughs consists either of poultry netting or ¼-inch iron rods, or a combination of the two. Where the tank is to be moved after being made, both the poultry wire and rods are recommended as shown in sketch "C." The spacing of the rods may vary somewhat but will generally be about 4 inches center to center.

Where the trough is cast in place and will never be moved, either the rods or poultry netting is sufficient.

Since the troughs are all of approximately the same section, the capacity will vary only with the length, and for each 10 feet of length about 1½ sacks of cement, 3 cubic feet sand and 5 cubic feet of gravel or crushed stone will be required.

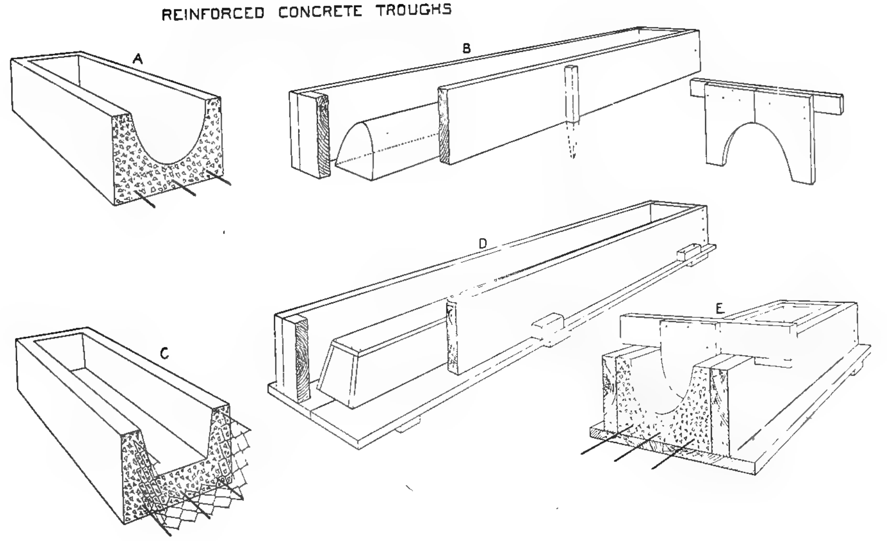


Figure 127 Concrete Troughs suitable for use in concrete hog houses.

Concrete Root Cellars

IN most of the Northern States root cellars are commonly used for the storage of potatoes, turnips and other vegetables from the time of gathering until marketed. Such cellars are also used for the storage of roots which are fed to cattle.

Concrete is an ideal material with which to construct root cellars, because it will not rot out or wear out, as will most other substances. Many of the first cellars were constructed of wooden planking, but experience has shown that this material cannot be depended upon for any considerable length of time, because, being surrounded and covered with earth, the planks are always moist, and beside being affected by the moisture, bow out of place from the pressure of the dirt. It is quite general practice, however, to build root cellars so that the floor is a few feet below the ground line and with this construction it is not necessary to bank the ground up so high around them. In a few cases root cellars have been built with floors on the ground level and dirt has been banked up around the cellar so as to completely cover it, effectually protecting the walls from the heat of the sun.

It is a good plan to provide several openings in the roof through which the vegetables may be shoveled when filling the cellar. These openings need not be larger than 2 feet square, and should be provided with suitable covers to fit tightly into place when not in use. A ventilator should also be provided in the roof of the cellar.

The space beneath the approach to the second floor of a barn is often utilized for the storage of roots. With such an arrangement it

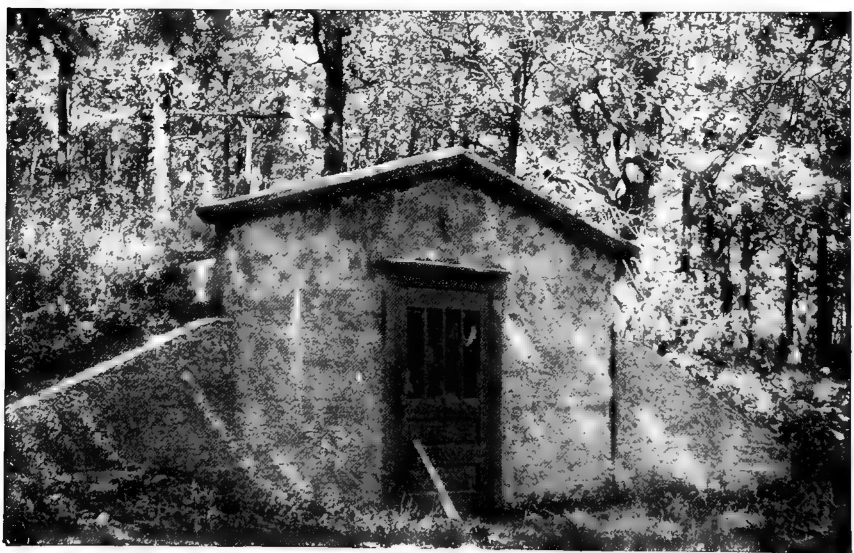


Figure 128. Concrete Root Cellar, University Farm, St. Paul, Minnesota.

is possible for wagons to stop on the approach and unload the vegetables directly through the opening. A root cellar so located is convenient to the barn and double use is thereby made of the walls, which also take the place of retaining walls for the approach. The design of the arch top root cellar shown in Figure 130, page 148, closely follows that suggested in Bulletin No. 90, by Professors J. H. Shepperd and O. O. Churchill of the North Dakota Experiment Station, while the second design, of a small flat top cellar, was recently prepared by our Information Bureau in answer to an inquiry. Additional information regarding root cellars can be secured by addressing Professor J. H. Sheppard or Professor R. M. Dolve of the North Dakota Experiment Station at Fargo.

Reinforced Concrete Root Cellar with Arched Roof

THE design presented in Figure 130 is for an arched top root cellar with a capacity of 5000 bushels when the bins are filled to a height of 6 feet. Larger or smaller cellars may be built without any other alteration to the plan than to lengthen or shorten the building as desired.

The footings upon which the walls rest are 12 inches broad and 12 inches deep, the top of the footings being 6 feet 6 inches below ground level, as shown in section A-A, Figure 130. The inside wall forms are constructed of 2 by 6's running horizontally braced by 2 by 4's running vertically and spaced 18 inches center to center. The 2 by 4's extend from the top of the wall to the sub-grade. The column forms are constructed of two 2 by 10-inch and two 2 by 8-inch boards, and rest on the column footings, forms for which are shown in Figure 112, page

Figure 129. A Good Concrete Root Cellar, on Iowana Farm, near Davenport, Iowa. The cellar is almost entirely below ground, and has a reinforced concrete arched roof.

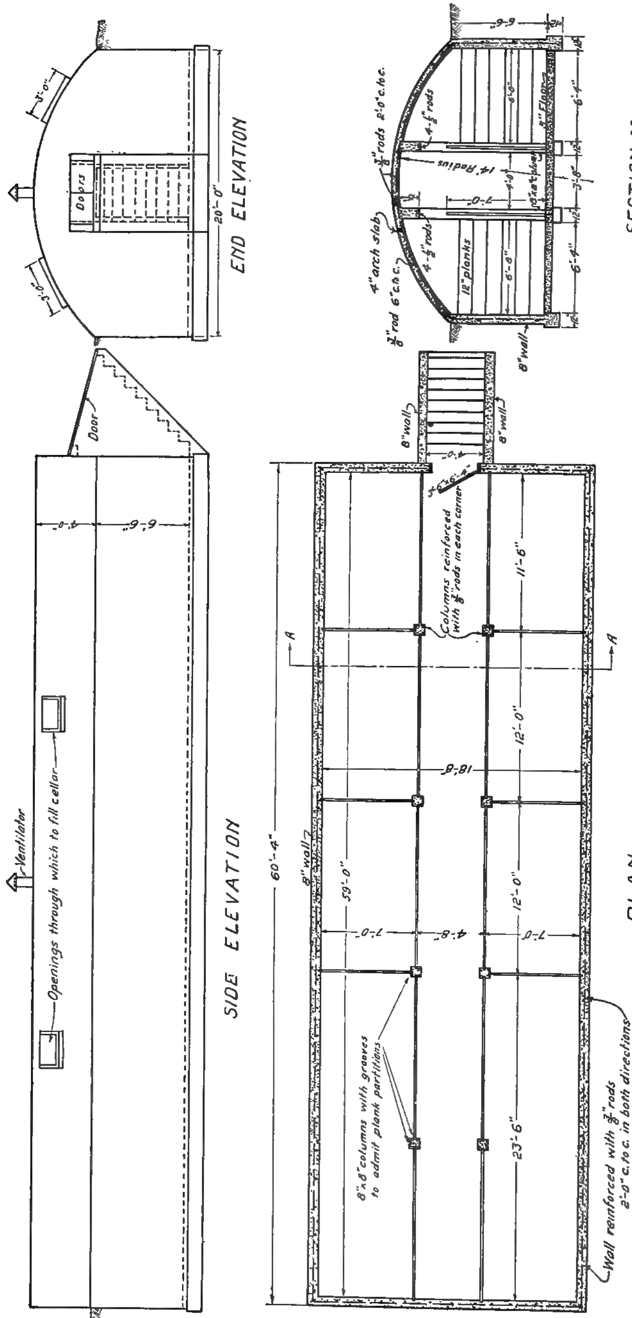


Figure 130. **Plan and Elevation of an Arch-Top Root Cellar of Reinforced Concrete Construction. Adapted from a design by Prof. R. M. Dolve, of the North Dakota Experiment Station.**

127. The column forms are braced by 2 by 4's placed on opposite sides of the column, and wired together as shown in Figure 131. The 2 by 4's should be spaced no farther than 18 inches apart, center to center.

The girder forms are constructed of 2 by 6 inch boards and are supported by two 2 by 4's wired together, there being two such supports between each column. These supports may rest on blocks or flat stones, and can be brought to the desired height by wedges. On the girder forms are blocks fastened to support the three 2 by 12's as shown. The 2 by 12-inch pieces can be cut to shape by the following method: Draw a circle on the barn floor with a radius 2 inches less than the radius required to give the proper curvature to the arch roof, which is 14 feet. For this purpose use a sweep with a soft pencil attached to one end. Do not use cord and chalk as the former will stretch enough to distort the circle and the latter will make too wide a line.

The concrete should be mixed to such a consistency that it will flow readily to all parts of the forms with very little puddling or churning. It should be well spaded to force the larger stones back from the surface and bring the finer material to the surface, thus producing a more dense concrete. The roof slab and girder should be cast in one operation, the forms (shown in Figure 131) having been designed with that idea in view

The reinforcing for the wall consists of 3/8-inch round rods spaced 24 inches apart, center to center, both vertically and horizontally. The roof is reinforced with 3/8-inch round rods spaced 6 inches, center to center, in a crosswise direction, and 2 feet, center to center, longitudinally. The forms should be left in place from two to three weeks after the placing of the concrete, or until all doubts have been removed as to the ability of the structure to carry the loads to be imposed upon it.

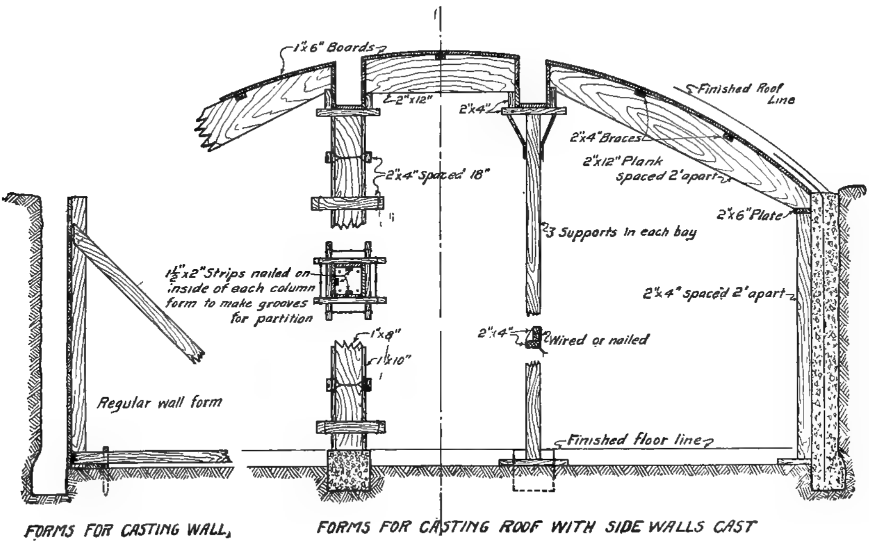


Figure 131. Sectional Detailed View of Root Cellar Wall and Forms.

Four openings, each 3 feet square, are provided in the roof, through which the cellar may be filled. Concrete casings for these openings may be easily formed, and should project about 2 inches above the surface so that a cover with a rim surrounding the casing may be placed on when the opening is not in use. The casing may be made with the aid of a small box mold. The ventilator shown in the figure should also be in place before concreting. The concrete stairway should preferably be covered with doors, so as to keep out snow and rain.

The interior is divided into a central alleyway, 4 feet 8 inches wide, and ten storage bins, five on either side of the alley. This arrangement gives bins of convenient size, but any other arrangement desired can easily be worked out. The plank partitions are held in place by grooves in the walls and in the posts, making them readily removable.

Table of Materials

	Conc. Cu.Yds	MIX-TURE	CEMENT Sacks	SAND		STONE	
				Cu.Yds.	Cu.Ft.	Cu.Yds.	Cu.Ft.
Footings	5.68	1:3:5	27.2	2.95	79.8	4.88	131.9
Column Footings	0.30	1:3:5	1.4	0.16	4.2	0.26	7.1
Floors	16.70	1:2:3	116.2	8.68	234.5	12.86	347.2
Walls, including entrance way	27.90	1:2½:4	155.2	14.60	394.0	22.90	618.0
Stairs	0.89	1:2½:4	5.0	0.45	12.2	0.73	19.7
Columns	1.15	1:2:4	6.0	0.53	14.3	1.06	28.6
Beams	3.64	1:2:4	22.9	1.60	43.2	3.20	86.4
Roof	16.18	1:2:3	112.6	8.41	227.2	12.46	336.4
Total	....	.....	446.5 (111¾ Bbls)	37.38	1009.4	58.35	1575.3

Approximate amount of Reinforcing required:

5200 feet ⅜-inch rods . . . . Weight 1950 Lbs.
482 feet ½-inch rods . . . . Weight 322 Lbs.
Total . . . . 2272 Lbs.

Reinforced Concrete Root Cellar with Flat Slab Roof

IN most cases where a small root cellar is required the design shown in Figure 132 will probably answer. The cellar consists of a rectangular room or cave with wing walls extending across the front, to retain the dirt fill around the structure and prevent it from working down around the doorway. The cellar may be located wholly, or partially, below ground as desired, but the load upon the roof slab should be limited to the weight of 2 feet 6 inches of dirt, or its equivalent. If the cellar is located below ground it must not be driven over. This cellar is of such a design that it may be made larger or smaller by merely changing the length.

The footings, which must be located below the frostline, need be only 9 inches in depth and 14 inches in width. They may be constructed without forms, but the top should be leveled off sufficiently to provide a

good base for the wall forms. The walls should be made 8 inches thick to withstand the pressure of the earth from without.

The door opening in the front wall of the structure should be 3 feet in width and 6 feet in height, and may be formed by placing within the wall forms a suitable frame. The concrete above the doorway in

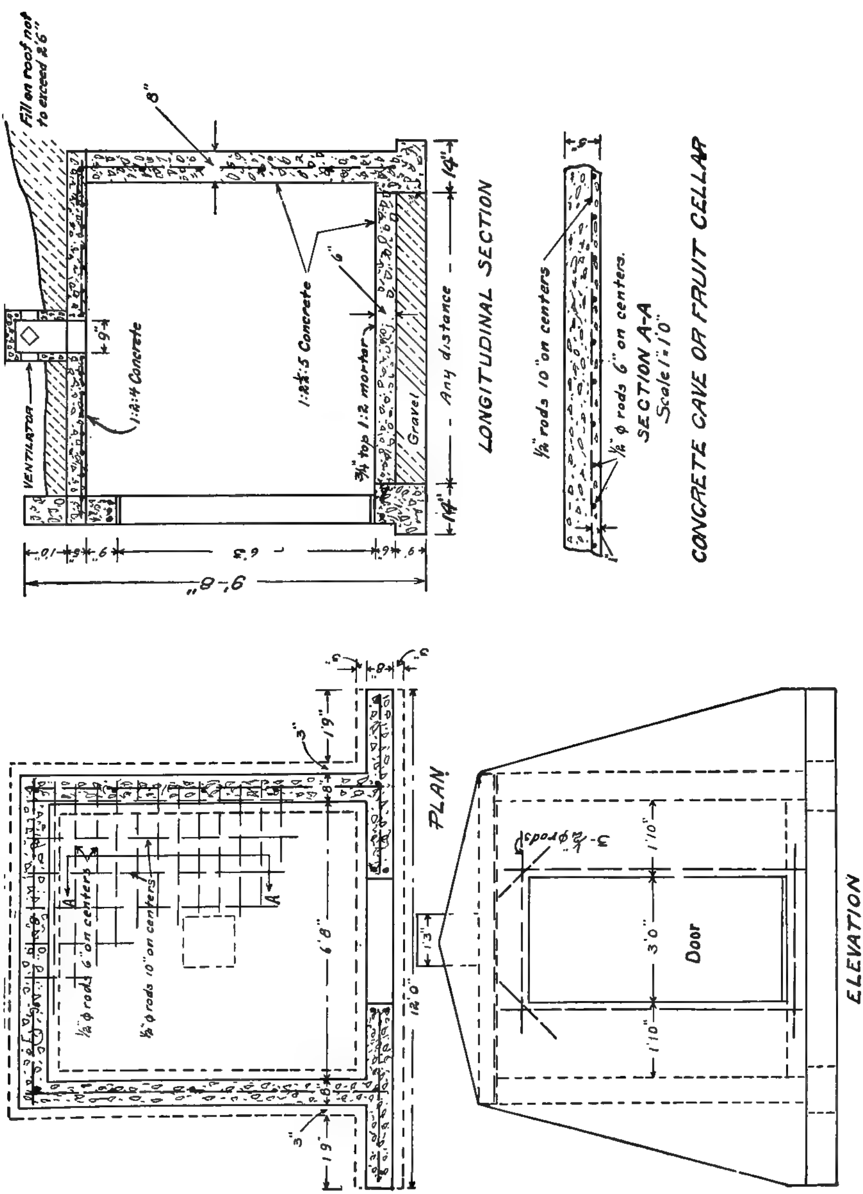


Figure 132. Plan and Elevation of a Flat Top Reinforced Concrete Root Cellar.

Figure 133. Monolithic Root Cellar with Wing Walls, on a Minnesota Farm, property of E. J. Longyear, Minneapolis.

the front wall will act as a beam, and should be reinforced with three ½-inch round rods as shown in the elevation and longitudinal section.

The roof slab should be made 5 inches thick, and should be reinforced with ½-inch round rods spaced 10 inches apart, center to center, from front to back of the structure, and 6 inches apart, center to center, in a crosswise direction. The spacing of 10 inches, center to center, will be maintained regardless of the length of the cellar. All reinforcing rods in the roof should be bent so that the ends will extend down into the walls a distance of 12 inches. The roof should be provided with a small ventilator. For further instructions as to the construction of the roof, the reader is referred to pages 58 to 67.

Proportions (See page 157).
Footings, Specification D.
Walls, Specification C.
Floor and roof, Specification A.

Table of Materials

	Conc. Cu.Yds	MIX-TURE	CEMENT Sacks	SAND Cu.Yds.	SAND Cu.Ft.	STONE Cu.Yds.	STONE Cu.Ft.
Footings	1.95	1:3:5	9.1	1.01	27.4	1.68	45.3
Floor	2.57	1:2:3	17.9	1.33	35.8	1.98	53.4
Walls	10.7	1:2½:4	59.4	5.45	147.0	8.77	237.0
Roof	2.66	1:2:3	18.5	1.38	37.4	2.05	55.3
Total	...	....	104.9 (26¼ Bbls)	9.17	247.6	14.48	391.0

Steel required for Roof Reinforcing:

40 ½-inch round rods, 8 feet long......Total length 320 Feet (Cross Reinforcing)
10 ½-inch round rods, 21 feet long..... Total Length 210 Feet (Longitudinal Reinforcing)

Total....................530 Feet = 354 Lbs. Steel.

Concrete Machine Sheds

IT is a well known fact that the farmers of this country are extremely negligent when it comes to the matter of protecting their farming implements. Even the largest and most expensive pieces of machinery, such as harvesters and traction engines, are frequently seen standing out exposed to the weather, resulting in an enormous annual loss through depreciation. The International Harvester Co. states that experience shows 75 per cent of the annual depreciation is due to exposure to the weather, while only 25 per cent is due to wear and tear. This means that by keeping farm machines in a good dry house and otherwise caring for them when not in use, their period of usefulness can be increased to three or four times the life of the machines left exposed to the weather.

Occasionally space is provided in the barn for the storage of the implements, but in most cases room for storage purposes is at a premium, and the arrangement of the barn makes it necessary frequently to move stored implements from one location to another in order to facilitate the work. This and other considerations make it desirable to store all machinery, tools, etc., in a building especially designed and built for the purpose.

The size and shape of the implement house should conform to the number and size of the objects to be stored. For this reason it is difficult to present in a single design anything likely to be applicable in a large number of cases. The house may be made with either all four sides closed, or with one side open. In case the house is put up with an open side, this side should be to the south or the east, to admit the sun and keep out winter storms which generally come from the north or the west. In houses having all four sides closed, several large doors should be provided along one side to facilitate the movement of implements in and out. To give plenty of room for the larger implements, the house should be about 16 feet deep and the distance between columns or upright supports should be about 12 feet to take in the widest machines. The roof need not be over 8 feet in height and may be lower if desired. The house should be built long and low, somewhat after the general lines of a wagon shed. Future additions can be added to the end, thus giving the house the advantages of a unit structure.

In a recent number of the Dakota Farmer, W. Leonard, of Spink County, South Dakota, describes his machine shed in the following words:

"This shed is 84 feet long and 16 feet wide, standing on slightly sloping ground. The wall is 6 inches thick, made of concrete. The foundation at the high corner is 6 feet high, and the lower corner is 3 feet high.

"Will tell you what we have in this shed at present: The first three apartments are 12 feet, from center to center of posts, and the other six are 8 feet. In the first apartment on the north end, there are two 11-foot grain drills, one broadcast seeder, two listers and a walking plow; in the second a disc, manure spreader, corn planter and gang plow. In the third are two grain binders and bottoms for plows; and in the first two 8-foot apartments are two farm wagons. In the third and fourth are a corn binder, a corn plow, top buggy and a surrey. The south end is used as a repair shop, where a little of everything is at hand. Overhead in this shed is plenty of room for seed corn, side-boards, tongues, binder canvases and other things."

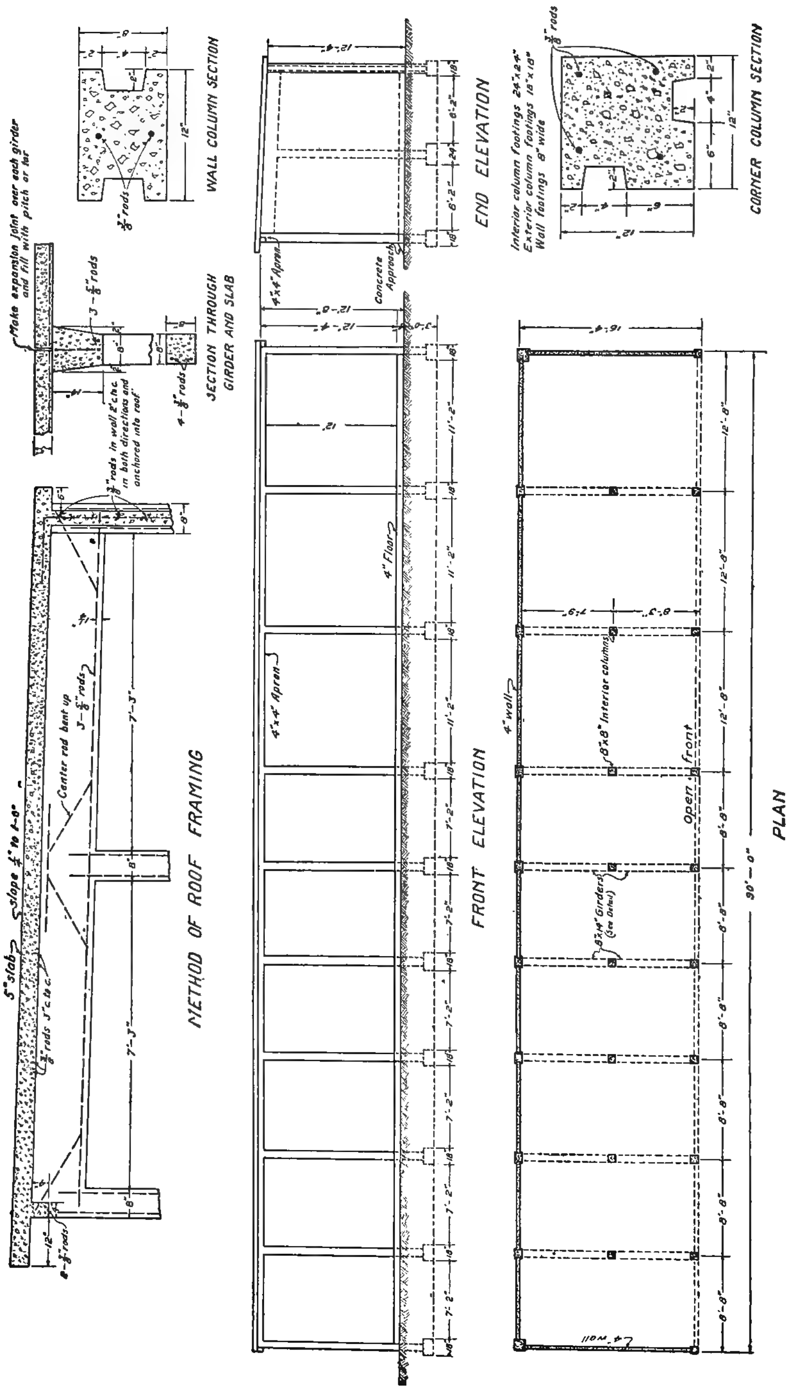


Figure 134. Reinforced Concrete Machine Shed.

A Modern Concrete Machine Shed

THE all-concrete machine shed, shown in Figure 134, was designed from Mr. Leonard's description and may be changed in size to accommodate a larger or smaller number of implements without varying but slightly from this general plan.

The foundations are of concrete with footings 18 inches square. These support 8 by 8-inch reinforced concrete columns grooved to hold in place the concrete slabs which are cast between them. These columns may be cast in a mold similar to that shown in Figure 122, page 140, and the slabs may be cast in ordinary wall forms such as are described on pages 32 to 35. If desired, the walls may be built of concrete blocks without wall columns, although a greater quantity of materials will be required if this be done. It is also possible to use columns, filling up the panels between them with veneer block, 4 inches thick, or with cement plasterwalls.

Figure 135. Entrance to Concrete Root Cellar of Mrs. Gallup, Rochester, Wisconsin.

The roof is of beam and slab construction, and is supported entirely on the columns. After the columns have been placed in position, the forms for the roof beams and slabs are put up, and the beams and slabs concreted. It will be noticed that the reinforcing in the columns protrudes about 8 inches up into the roof beams for the purpose of securely tying the columns and beams together. The reinforcing of the interior columns and beams, as well as the expansion joints in the slab over each beam, is shown in the section through the girder and slab.

After the walls and roof are constructed, a concrete floor 4 inches thick should be laid. For work of this kind a one-course floor is desirable. The floor should be finished off with a wood float and a small amount of mortar used if necessary to secure a sufficiently smooth surface. The floor should be given a slight pitch toward the front of the structure in order to insure good drainage, in case it is desired to wash vehicles within the shed.

Proportions (See page 157).

Foundations, footing and apron, Specification D.

Roof and floors, Specification A.

Columns and beams, Specification B.

Table of Materials

	VOL. Cu. Yds	MIX-TURE	CEMENT Sacks	SAND Cu. Yds.	SAND Cu. Ft.	STONE Cu. Yds.	STONE Cu. Ft.
Foundations and Footings	6.83	1:3:5	31.7	3.55	95.9	5.97	161.3
Apron	0.38	1:3:5	1.8	0.20	5.3	0.33	8.8
Walls	17.20	1:2½:4	95.6	8.77	236.8	14.1	380.8
Floors	17.30	1:2:3	120.4	9.00	242.9	13.32	359.7
Columns	7.10	1:2:4	43.0	3.20	86.5	6.30	170.0
Beams	4.50	1:2:4	27.0	2.02	54.5	4.00	108.0
Roof Slab	24.40	1:2:3	169 8	12.69	342.6	18.79	507.3
Total	.....	......	489.3 (122½ Bbls)	39.43	1064.5	62.81	1695.9

Approximate amount of Reinforcing required:

408 feet, ⅝-inch round rods.................Weight 430 Lbs.
8736 feet ⅜-inch round rods.................Weight 3300 Lbs.

Total..............................3730 Lbs.

(Add 10 per cent extra steel to allow for waste.)

Figure 136. Monolithic Root Cellar on the Farm of J. S. McMillan, Republic, Missouri. The arched concrete walls of the cellar proper are covered with earth, leaving only the entranceway visible.

APPENDIX

Specifications for Portland Cement Concrete*

Specification A—1:2:3

Proportions: 1 sack Portland cement to 2 cubic feet coarse, clean sand, to 3 parts screened gravel or crushed stone, varying in size from ¼ inch to 1 inch.

Materials required for 1 cubic yard of concrete: 1.74 barrels (7 sacks) cement, .52 cubic yards (14 cubic feet) sand, .77 cubic yards (20 cubic feet) stone.

Suitable for the walls and floors of tanks and other work requiring watertight concrete of great strength; also sills and lintels without mortar surface, one course floors, roofs, fence posts, etc.

Specification B—1:2:4

Proportions: 1 sack Portland cement to 2 cubic feet coarse, clean sand, to 4 parts screened gravel or crushed stone varying in size from ¼ inch to 1 inch.

Materials required for 1 cubic yard of concrete: 1.51 barrels (6 sacks) cement, .75 cubic yards (21 cubic feet) sand, .89 cubic yards (24 cubic feet) stone.

For beams and columns sustaining great weight.

Specification C—1:2½:4

Proportions: 1 sack Portland cement to 2½ cubic feet coarse, clean sand, to 4 parts screened gravel or crushed stone varying in size from ¼ inch to 1 inch.

Materials required for 1 cubic yard of concrete: 1.39 barrels (5½ sacks) cement, .51 cubic yards (14 cubic feet) sand, .82 cubic yards (22 cubic feet) stone.

For the body of concrete blocks, sills and lintels which are given a mortar surface, walls less than 6 inches in thickness, one-course floors and pavements.

Specification D—1:3:5

Proportions: 1 sack Portland cement to 3 cubic feet coarse, clean sand, to 5 cubic feet screened gravel or crushed stone varying in size from ¼ inch to 1½ inches.

Materials required for 1 cubic yard of concrete: 1.16 barrels (5 sacks) cement, .52 cubic yards (14 cubic feet) sand, .86 cubic yards (24 cubic feet) stone.

For foundations and basement walls greater than 6 inches in thickness.

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*Note. The specifications as here given are arbitrary proportions recommended for general practice. Special proportions are referred to in the text for special work, such as the mixture of 1:2½:2 recommended for unit slab construction.

Consistency of Concrete

FOR the foundations and walls of buildings enough water should be used in the concrete so that it will flow to all parts of the mold with a small amount of puddling and spading. For columns, beams, floor slabs and roof slabs, the mass should have a quaky consistency such as will tend to flatten out of its own weight when piled. The mortar surfaces of floors should be mixed with sufficient water to make it work easily, but an excess of water should be avoided. Concrete blocks, sills, and lintels should be mixed just as wet as possible with the block machine employed. Blocks and sills made of a mixture wet enough to be quaky when placed in the mold will be dense and watertight. Blocks made with dry materials are porous, lack strength, and present a dead appearance. It must always be remembered that the bonding quality of cement in concrete depends upon a hydraulic action between the cement and the water in which each plays an equally important part. The lack of sufficient water to complete this action is therefore as detrimental as the lack of cement.

Small Concrete Bridges and Culverts

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Foreword

DURING the last decade, confidence in concrete bridges has been growing steadily, but the great floods of 1913 crystallized public opinion in an instant and thousands of temporary structures demolished will be rebuilt largely of concrete.

For the purpose of assisting in the design and construction of concrete bridges, this booklet has been published. In it will be found general suggestions and designs as well as tentative specifications. Attention is particularly directed to the designs of several state highway departments which not only bear the stamp of authority, but indicate the general adoption of concrete for the construction of highway bridges and culverts.

While somewhat exhaustive data on the methods of building and the correct design of small concrete bridges and culverts have been published in this book, for the purpose of enlightening County and Municipal officials—yet the necessity for a competent engineer on larger structures, and also on the smaller ones when unusual conditions prevail, has been emphasized.

Public officials and engineers will, perhaps, find much of value to them in this book.

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Concrete Highway Bridges and Culverts

Table of Contents

Small Concrete Bridges and Culverts

Introduction

Historical

The construction of highway bridges in this country began to assume practical proportions about 1800. The first bridges were built of wood, at that time found in great abundance, and consisted of heavy timbers and planks roughly pinned together. They were built with little, if any attempt at economical design. An effort was made to protect the members by wooden sides and roof, but few were ever painted to preserve the timbers. Some of these wooden bridges are in existence to-day. The economical design of highway bridges was first investigated by Squire Whipple, of Utica, New York, who originated the Whipple truss and who published a book on the design of highway bridges about 1845.

Prior to 1850 few iron bridges were erected. The first metal bridges were of cast or wrought iron, and it was not until about 1870 that these materials were replaced by steel. Probably the first reinforced concrete bridge in this country was erected at San Francisco, about 1889. From this beginning, the use of concrete in bridge construction has grown, until to-day, progressive communities in every section of the country are adopting this type of construction.

Figure 1. Concrete and Steel Bridges at Tiskilwa, Ill.

Purpose of The Book

Culverts and bridges stand in intimate relation to the improvement of the public highways, but the economy of building these structures of durable and permanent materials and according to intelligent, economic design, has not generally been recognized. While many communities still continue the old-fashioned, inadequate and expensive methods of construction and repair of their bridges and culverts, yet modern traffic conditions demand that the construction of bridges and culverts shall keep pace with the industrial development of the country.

The administration of road improvements in the United States is placed in the hands of local officials. The bridge improvements of many of these communities are mainly the construction and repair of culverts and small span bridges which do not justify the expense of securing the advice of an engineer. This book is intended to assist the local officials in securing a proper, intelligent and economic design for small bridges and culverts of less than 20-foot span.

Figure 2. Concrete Bridge, Kane County, Illinois.

Structures larger than 20 feet in span should never be undertaken without consulting an engineer. Many states maintain an engineer who will give free engineering advice to local officials requesting his services and the State Highway Commission should always be consulted by communities contemplating extensive bridge improvements.

Economic Considerations

The substantial construction of bridges is an important feature in the welfare of any community. Traffic conditions are demoralized by unsafe bridges and culverts. When considering the construction of a highway bridge, traffic conditions should be considered carefully and the bridge constructed not only to meet the present traffic requirements, but also that of the future. The bridge of to-day must be strong enough to allow the passage of heavy traction engines, road rollers and motor trucks. The bridge should advertise the progressive ideas and business activity of the community and therefore should be built of a structural material which is permanent and will not require costly items of repair every few years.

Advantages of Concrete

Concrete is peculiarly fitted for this construction. Concrete bridges are permanent and if properly constructed, cannot wash out; require neither painting nor repairing; are made of materials which can be purchased in the vicinity, and so permit the greater part of the cost of structure to be spent at home. For simplicity of

construction and durability, the concrete bridge leads all other types.

General Construction Data

A. R. Hirst, Acting State Engineer of Wisconsin, has prepared the following table, giving estimated cost of maintaining eight of the most common kinds of culverts over a period of one hundred years.

Table No. 1. Showing Cost of Maintaining Eight of the Most Common Kinds of Culverts Over a Period of 100 Years

KIND	Shape	Size	Cost	Cost for 100 Years
Wooden Box	Rectangle	15″ square	$16.80	$252.00
Concrete Box	Rectangle	15″ square	40.00	40.00
Cast Iron	Semi-circle	16″ diam.	57 90	97.80
Cast Iron	Sector	18″ diam.	65.25	112.50
Cast Iron	Circle	18″ diam.	92.40	166.80
Vitrified Tile	Circle	18″ diam.	42.00	42.00
Corrugated Steel	Circle	18″ diam.	50.40	196.00
Circular Concrete	Circle	18″ diam.	35.00	35.00

Proper Location

After examining the foundation at a proposed bridge site, it is often found necessary to change the location of the bridge in order to secure a more suitable and economical foundation. In the layout of a new bridge site, attention should be given to the probable later improvement of the road, and this consideration should influence the position of the new structure. In all cases, the general alignment of the road should be planned so as to be practically straight. Short, sharp curves at the approaches of a bridge are to be avoided. It is not unusual to see a bridge built to fit the stream only, utterly disregarding the sharp turns necessary to approach it.

Foundations

The question of foundation is an important one, as upon it depends the stability of the whole structure. The word "foundation" is used to indicate the natural bed or soil upon which is placed the footings for the abutments of a bridge or the walls of a culvert. The amount of attention to be given the foundation will vary with the size and importance of the structure, upon the loads which it is to carry, and upon its type. No part of bridge construction requires more care and skill than the determination of the proper depth to the foundation and the construction of the footings.

The different foundations, ranging as they do from hard rock to the light loam soil of the prairie states, will vary greatly in their bearing power. Good judgment and experience aided by a careful study of the soil, should enable the practical man to determine with a reasonable degree of accuracy its supporting power. The safe supporting power of the various soils is given in the following table from "A Treatise on Masonry Construction," Prof. Ira O. Baker, of the University of Illinois."

Table No. 2

	Supporting Power in Tons per Sq. Ft.
Rock—in thick layers, in natural bed	200
Clay—in thick beds, always dry	4
Clay—in thick beds, moderately dry	2
Clay—soft	1
Gravel and coarse sand, well cemented	8
Sand—compact and well cemented	4
Sand—clean and dry	2
Quicksand, loam soils	0.5

For a rock foundation, it is, as a rule, only necessary to cut away the loose and decayed portions of the rock and prepare a surface as nearly as possible at right angles to the direction of the pressure. For foundations other than natural rock, it is necessary to see that the footings are below the frost line and that the foundation has sufficient bearing power to sustain the loads which will act upon it. Moreover, in soils of this character, care must be taken to see that the abutments are protected against undermining by currents of water.

When the structures are to be located in soft or swampy ground, where it is impossible to secure a firm, natural foundation, special forms of foundations are necessary such as wooden piles or reinforced concrete floors which distribute the weight over a greater area. In instances of

Figure 3. Concrete Bridge, near Oregon, Illinois.

this kind, each case must be taken as a separate engineering problem of its own, and knowledge of the best method to be employed can only come with experience.

Determination of Size of Waterway

The determination of the size of waterway required is a problem that does not admit of an exact calculation; however, it is a matter which demands intelligent consideration. If the waterway of a culvert or bridge is too small, it is liable to cause a washout, entailing interruptions to traffic and costly repairs. On the other hand, if it is too large, the cost of construction is unnecessarily increased.

Although there are several theoretical formulas for determining the area of waterway for small bridges and culverts, none of them gives close and accurate results, and they are used more as an "aid to the judgment, than for actual results." The span and height of a bridge or culvert can best be determined by careful observation of the stream and the amount of water which it carries at flood times. A cross section of the stream at some narrow place should be measured at a time of high water. This will enable one to determine the proper area of waterway with a reasonable degree of accuracy.

Figure 4. Concrete Bridge, McLean County, Illinois.
12-foot span; 16-foot roadway; Cost $300.

Types of Bridges

Concrete bridges may be classified as slab or girder bridges and arch bridges. Slab and girder bridges are those in which the pressure from the bridge floor acts vertically upon the abutments. They consist either of flat slabs or of combined beams and slabs of concrete reinforced with steel. Arch bridges are curved, and the pressure upon the supports is not vertical but inclined. Flat slab construction is suitable in level countries and for locations where the foundation is of soft material. Arches are especially economical in localities where the roads can be built at a considerable height above the streams and where there is rock, gravel or similar hard soils which offer solid foundation.

A flat slab bridge consists essentially of a concrete floor of uniform thickness reinforced with steel and resting on the abutments. The re-

inforcement in the slab consists of steel rods running lengthwise of the roadway, which take up all tension stresses due to loads on the bridge, while rods are run at right angles to the roadway to reinforce the slabs against temperature stresses. The distance from the bottom of the slab to the top of the footing should vary to meet the requirements of the waterway.

The arch bridge consists of a curved slab the thickness of which increases from the crown to the springing line. The arch may either be elliptical or semi-circular in shape, of plain concrete or reinforced with steel rods. Each span of both types is a special design in itself, and it is necessary to have exactly the correct amount of concrete and steel rods for each individual design.

Figure 5. Concrete Culvert on a road leading to Indianapolis along the right of way of the Pennsylvania lines.

Culverts

The term, culvert, is generally applied to structures built to provide waterway through high embankments or to carry surface water from one side of the roadway to the other. The term, bridge, is given to those structures spanning natural waterways. Authorities disagree as to the dividing line between the two. One authority applies the name, culvert, to any structure less than 30 feet in span, while another limits the name to any structure under 6 feet in span. For convenience, a culvert will be considered as 8 feet and less in span, while all structures over 8 feet in span will be classed as bridges.

The bridge and culvert designs shown in Figs. 17 and 25 are for loads as follows: Dead loads, concrete 150 lbs. per cubic foot, earth fill, 100 lbs. per cubic foot, a uniform live load of 125 lbs. per square foot, and a concentrated load of 24 tons on two axles 10 feet apart, 8 tons on the front and 16 tons on the rear axle. This load was considered as acting over a width of 12 feet. The moment for both the uniform live load and the concentrated load was calculated and the greater added to the dead load moment to determine the dimensions of the slab.

The compression allowed in concrete has been taken at 600 lbs. per square inch for concrete 60 days old, with a corresponding stress in steel in tension of 16,000 lbs. per square inch.

In designing the arch bridge and culvert shown in Figures 19 and 29, the empirical rules indicated by the best American practice were used to obtain thickness of crown and springing line. The line of resistance of the arch was then determined and located graphically on the profile of the arch. This line of resistance was determined for different live loadings and found to lie within the middle third.

Selection of Aggregate

The materials mixed with the cement to form concrete, are commonly referred to as "aggregates." Careful selection of all aggregates is necessary to obtain good concrete. They must be clean, coarse, hard and well graded. Clean, because if the separate particles are covered with a coating or film of any kind, the cement cannot form a bond with them. Coarse, because a coarse aggregate presents a smaller surface for the same volume than a fine one, thus making a stronger concrete with the same proportion of cement.

Concrete is no stronger than the aggregate composing it, consequently the aggregate must be hard and remain hard under all weather conditions. Some sands and gravel contain shale-like particles which, after exposure to the weather for a short time, go to pieces. Occasionally, stone which is not hard or is of a chalky nature, is crushed for use in concrete and naturally will not give good results.

The aggregate must be well graded. An ideal aggregate is one which contains just enough of different sized particles to produce a mass with a minimum amount of voids or air spaces and possesses, at the same time, a maximum amount of coarse material.

Those particles of the aggregate which will pass a one-quarter inch sieve are generally considered as sand. Sand must be free from an excessive amount of fine material. A mixture of cement and fine sand cannot possibly give as great strength as a mixture of the same proportion of cement and coarse sand; therefore, the use of fine sand should be avoided. If it is the only sand at hand, a coarse material should be obtained to mix with it, or a correspondingly larger proportion of cement used.

The coarse aggregate, either screened gravel or crushed stone, should all be coarser than one-quarter inch. In reinforced concrete work, where the shape and position of the reinforcing steel must be considered, the size of the aggregate should be such that the concrete can readily be placed about the steel. In ordinary work, 1½-inch gravel or stone will be as large as can be used.

Proportioning

The materials should be proportioned accurately. One sack of cement (94 pounds net), is considered one cubic foot, and each batch of concrete should be some multiple of one sack. The practice of shoveling sand and gravel directly upon the mixing platform or into the mixer without measuring, should never be permitted. It is best to measure materials in an accurate manner. This can be accomplished by measuring them in wheelbarrows, the capacity of which has been previously determined, providing care is taken to see that the wheel barrows are properly loaded each time.

In many communities it is common practice to use gravel as it comes from the gravel bank, even though the amount of fine material or sand

contained is very much larger than it should be. This material, as it comes from the natural bed or deposit, is seldom suitable for concrete without screening. The sand is in too large proportion, and in order to obtain the best results, the gravel should be screened and the sand and coarse aggregate remixed in the proper proportions. The relative proportions of sand and coarse aggregate in a mixture are as important as the proportions of cement, and should not be guessed at, but definitely determined.

To make this bad practice worse, it frequently happens, when the amount of fine and coarse material for the concrete is specified and unscreened gravel is used, the sum of the parts of the coarse and fine material is incorrectly taken as the amount of unscreened gravel permissible. A mixture composed of one part of cement and six parts unscreened gravel, is by no means the same as one composed of one part cement, two parts sand and four parts screened gravel or crushed stone. Even though the unscreened gravel contained the proper proportion of fine and coarse material, a 1:6 mixture of such a material would be approximately the same as one composed of one part cement, three parts sand and six parts coarse aggregate, that is, three cubic feet of sand and six cubic feet of gravel when mixed together make but little more than six cubic feet of material.

Proportions for Bridge Work

The concrete for the abutments of bridges and for the sides and footings of culverts, should be proportioned 1 sack Portland cement, 2½ cubic feet of sand and 5 cubic feet of screened gravel or crushed stone. For bridge and culvert floors and guard rails and also for the arch ring above the springing line, these proportions should be 1:2:4.

Figure 6. Flat Top Concrete Bridge with ornamental iron guard rail, near Geneva, Illinois.

Mixing

The mixing is just as important as any other part of the process of making concrete. After the proper materials have been selected and the proper proportions determined, the mixing must be done in a manner which will insure the covering of every particle of sand with cement and every particle of gravel or stone with the cement-sand mortar.

Where necessary to mix by hand, the sand should be spread upon a level watertight platform to a uniform depth. The cement should be spread evenly over the sand and the two mixed until the mass is uniform in color. On this mixture should be spread the required amount of gravel or stone which has been previously drenched, and the entire mass mixed until the coarse aggregate is uniformly distributed throughout the batch. Water should be added and the entire mass thoroughly mixed.

A machine mixer is much more certain and reliable than hand mixing, because the thoroughness of mixing is not dependent upon the fatigue or carelessness of the workmen, and therefore, each batch will be mixed uniformly.

The quality of the concrete depends largely upon the amount of water used. Generally speaking, wet concrete will give better results than dry. A dry mixture is not capable of developing all the strength of the cement and will result in a weak and porous concrete. On the other hand, an excess of water is often added when the same consistency could be secured by more thorough mixing. It will be noticed that the mass of concrete becomes more moist as the mixing proceeds, which shows that the particles are being forced in closer contact and that the object of the mixing is being accomplished. The materials should be mixed with sufficient water to form a concrete of such consistency that when placed in the forms and slightly tamped, it will quake like jelly.

Care should always be taken when adding water to the mixture. When mixing by hand, it is excellent practice to add the water in a spray such as can be obtained by the use of an ordinary sprinkler. The water should never be dashed from a bucket on the pile of materials and the mixing should always be conducted in a manner which will not permit the loss of cement through the running off of the surplus water.

The concrete should be placed in the forms as quickly as possible after being mixed, and the speed with which the concrete can be placed should govern the size of the batch. Under no conditions should concrete which has partially hardened be used.

Forms

The cost of concrete bridge work is, to a considerable extent, influenced by the expense attending the construction of the forms. The average carpenter who has not had experience in this class of construction, will, unless properly directed, greatly increase the cost A man not familiar with concrete form construction will invariably use too many nails, thus increasing the cost of removing the forms, also resulting in ruining a large amount of lumber for future use. A good rule to observe in construction of forms, is to avoid the use of nails whenever possible. Then too, the inexperienced man does not realize the enormous weight the forms have to carry and therefore, fails to make the centering sufficiently strong, allowing it to bulge and sag.

Any slight settlement of the forms occurring after the concrete has been deposited and before it has hardened sufficiently to sustain its own weight, is detrimental to the structure.

Improper bracing causes much loss of time and unsightly work. Many braces, however, can be done away with by using bolts. This applies particularly to the forms for abutments and wing walls where the opposite sides can be tied together by bolts or wires, thus causing the form on one side of the wall to help hold the opposite form in place. Proper methods of form construction and careful handling will save much lumber and allow the forms to be used several times. Where possible, the forms should be held and fitted into place by wedges which should be made of hardwood, well fitted and carefully driven to avoid shock. If the forms are supported upon a muddy creek bottom, it is necessary to place them on a firm foundation so that any strains on the new concrete due to settlement, may be avoided.

The face forms should be made of 2-inch lumber, sound and free from knot holes or other defects, and must be constructed so that they will be held rigidly in place. Where knot holes are unavoidable, they should be plugged with damp clay immediately before filling, or covered with a small piece of tin or building paper on the inside of the form. The inner face and both edges of tbe lumber should be dressed to insure a smooth finish on the exposed surface of the concrete and prevent ridges due to lack of uniformity in thickness of lumber. When the edges of the boards are not dressed, it is impossible to fit them closely together, thus permitting the cement mortar to leak through the cracks. These cracks will also cause unsightly ribs and ridges on the face of the finished structure. The forms should be cleaned carefully after each removal and

Figure 7. Flat Slab Bridge, Wayne County, Michigan. 7-inch slab; 8-foot span; 18-foot roadway. This view shows forms in place and method of bracing.

just before using again, it is advisable to treat or dress the face of the form with soap, paraffine or oil to prevent the mortar from adhering.

Time to Remove Forms

The weather has a decided effect upon the rate of hardening of concrete, thus a direct influence upon the time which the forms should remain in place. In the cool weather of spring and fall, concrete hardens slowly, so that the forms may need to remain several weeks before removal. Even in summer, during cool and cloudy weather, forms sometimes cannot be removed for several days.

Under the most favorable weather and construction conditions, no forms should be removed within less than 48 hours after depositing the concrete. For arches and floor slabs the forms must remain much longer than for the end and wing walls. The supports for floor slabs and arches must remain in place at least 28 days. Removing forms too soon has been the cause of more accidents than any other one thing; therefore, this is a point which should be considered carefully. It is the practice in some places to require, before removing the form, that the concrete in slabs and arches be sufficiently hard to cause a 20-penny spike driven into the concrete to double up before it has penetrated one inch.

Placing of Steel

When the forms have been erected and carefully measured, insuring that everything is true and to the line, the steel may be placed. In placing steel it is necessary to keep strictly to the design and see that pieces of the proper size are placed exactly as shown and carefully wired into position. Workmen are apt to be careless in placing steel and neglect the wiring together of the rods because it is a little tedious. Too much care cannot be exercised in this work for a rod in a certain position will perform an important function adding strength

Figure 8. Flat Slab Bridge, Wayne County, Michigan. 9-inch slab; 12-foot span; 18-foot roadway, reinforced with 1-inch twisted bars, on 11-inch centers. Cost $400.

and stability to a structure, while if allowed to shift a short distance, may be absolutely worthless besides leaving the structure weaker than it would otherwise be. The steel must be free from grease, dirt, or rust scale, when placed, because the presence of any of these on the steel will prevent the bonding of the steel and concrete. After the steel is placed, all dust and dirt should be removed and the forms thoroughly wetted before pouring the concrete.

Placing of Concrete

The concrete should be deposited carefully in place so that the aggregates and mortar will not become separated. The mass of concrete should be kept practically level, otherwise the water will drain from the concrete at the high places, carrying a portion of the cement with it. As the concrete is placed, it should be tamped, and that portion next to the form should be "spaded" thoroughly by using a specially designed flat-faced tool to force back the larger particles of the aggregate and bring the mortar in contact with the form. A spading tool of this characteer can be made from a hardwood board 1 inch by 4 inches, gradually sharpened to a chisel edge at the end. The sharpening should be on one side only and in using this paddle, the flat side should be placed against the form. This thorough spading of the concrete next to the forms is important as the smooth finish of the exposed surfaces depends upon the care with which the spading is done. The mixture must be quite plastic, as a dry mixture would have no tendency to flow. Concrete in the abutments should be deposited in continuous horizontal layers, thus avoiding any vertical joints. In the floor slab, the concrete should be placed for the full thickness of the slab at one time.

Where it is impossible to construct the abutments in continuous horizontal layers, it is best to divide the work in sections and complete each

Figure 9. Concrete Bridge, Town of Gorham, Ontario County, New York. Designed by New York Highway Commission. Span 18 ft. 6 in., Roadway 23 ft. Built by town labor. Cost $188.

section without interruption. This will make it necessary to provide for vertical joints at both ends of the section. So that the sections of the abutment will be keyed into each other, a groove should be formed in one end of each section. This groove can be made by placing a 4 x 8 timber vertically against the end wall of the form and removing before depositing the next section. Previous to placing, the 4 x 8 timber should be dressed slightly wedge shaped, so that it can be removed without destroying the groove.

For reinforced work it is necessary to use a slushy concrete. It should not, however, be so wet that the mortar is watery or will run away from the coarse aggregate leaving pockets in the finished work. The concrete should be "joggled" rather than tamped so that it will flow under and around the steel and will flow into place without disarranging the steel. Care must also be taken to see that the steel does not separate the larger particles of the aggregate from the mass.

Wherever concreting is unavoidably interrupted even for a short time, a weakened bond will occur between the new concrete and that previously placed unless special precautions are taken. The surface of the old concrete should be thoroughly wetted and a grout of cement and water mixed to the consistency of thick cream spread immediately before additional concrete is placed. Under no circumstances should this grout be allowed to become dry. The amount of water that will be required to wet the old concrete will depend upon a number of conditions, but its tendency to absorb water must be satisfied.

It often happens that at the beginning of a day's work, a white or yellowish soapy deposit is found on the surface of the previous day's concrete. This deposit is known as "laitance" and must be removed from the surface in order to secure a proper bond between the two days' work. Laitance occurs when concrete is mixed with an excess of water or is agitated excessively, or both, and is composed largely of very fine particles of cement separated from the concrete by the excess water. These fine particles in suspension in the water lose their life before they come to rest and are left on the surface of the concrete an inert mass when the water disappears.

Finish

In ordinary bridge work, the expense attending an artistic surface finish is hardly justifiable, and the surfaces are usually left as they are found upon the removal of the forms. The concrete takes the impress of flaws in the face of the forms and shows the grain marks of the lumber. Careful workmanship and good forms can do much toward getting a satisfactory finish, which again emphasizes the importance of using good tight fitting lumber of uniform thickness, dressed on one side and both edges. Care should also be taken during the removal of the forms to see that the edges of the work are not broken, nor the surface injured in any way.

Painting with a cement grout after the removal of the forms is sometimes resorted to, but it is not recommended, for unless it is done with great care, it will scale off after a short time, leaving the surface rougher and more unsightly than it would have been if not touched.

In public parks and private estates, where a more artistic finish is desired, some further method of surface treatment is necessary. The most common and effective methods are by brushing, etching with weak acids, or bush hammering. A complete description of these methods is given in "Concrete Surfaces," published and distributed by the Universal Portland Cement Co.

Figure 10 Concrete Bridge, Town of Canandaigua, Ontario County, New York. Designed by New York Highway Commission. Span 14 ft., Roadway 26 ft. Built by contract. Cost $950.

Abutments

The abutment of an ordinary highway bridge or culvert has two offices to perform; to support one end of the structure, and to keep the earth embankment from sliding into the water. The form of abutment to be adopted will depend upon the locality, but the wing abutment will be found to be most economical under ordinary conditions. In the wing abutment, the end wall acts as a support for the bridge and a retaining wall for the earth embankment, while wing walls which act as retaining walls only, are placed at an angle to the end wall of the abutment.

Typical Design for Abutment Forms

Figure 11 shows an end section of a wing wall and illustrates the method of placing and bracing the forms. The distance between wall forms is maintained by separator rods and twisted wires passing around the studding as shown in the figure. The wing walls for the bridge and culvert designs shown are of a typical design and the details shown in Figure 11 can be used with all.

Proportions

The proportions of the materials for plain concrete abutments as shown in the following designs should be 1 sack of Portland cement, 2½ cubic feet of sand and 5 cubic feet of screened gravel or crushed stone. These materials should be selected and mixed as described in the section under aggregates.

Angle of Wing Walls

The angle of wing walls to be adopted in any case will depend upon local conditions, whether the banks are low and flat or steep and rocky, and also whether the current is swift or slow. The more the wing departs from the face of the abutment as it swings around into the embankment, the greater the length required and the greater the

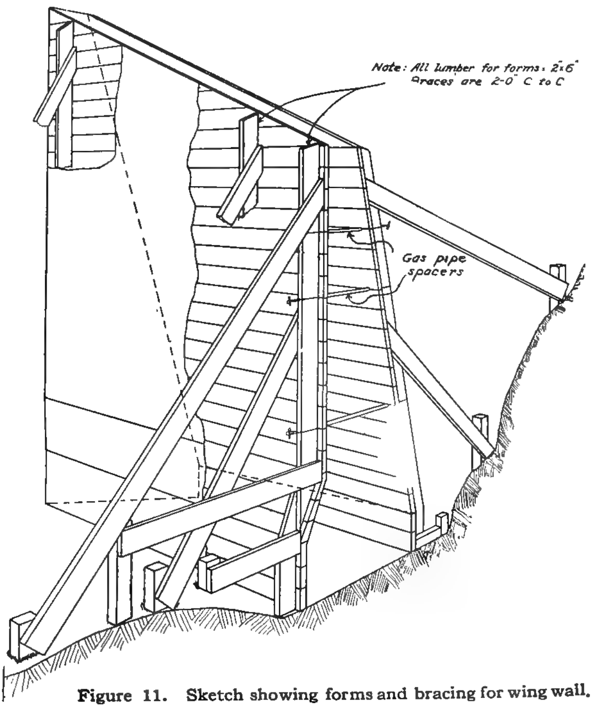

Figure 11. Sketch showing forms and bracing for wing wall.

thrust upon it. In the following designs for bridges and culverts, the wing walls are shown at an angle of 30 degrees to the direction of the stream flow. While this angle should be made to suit local conditions, 30 degrees will be found the most satisfactory for ordinary conditions. In no case has it been found practical to place the wings at an angle greater than 45 degrees.

The lengths of the wing walls will be governed largely by local conditions such as the character of the banks and the depth necessary to secure a good foundation. In the table of quantities accompanying each design, a definite length for the wing walls was assumed. This was necessary in order to obtain the quantities given in the tables, and the lengths assumed will undoubtedly be found the most economical under all ordinary conditions.

Drainage

Since there is always a considerable amount of loose earth fill back of the abutments, it is advisable to provide drain or weep holes through the abutments. This will prevent the collection of water back of the abutment which might prove extremely dangerous to the stability of the structure during cold weather, due to expansion of the water when freezing. A small drain placed in both wing walls and end walls about one foot above the normal water level of the stream will be sufficient.

Standard Width

The standard width of highway bridges varies in different sections of the country. In practically all the middle western states, the width is 16 feet; in some of the southern states 12 is not unusual, while in the eastern states 24 feet has become customary.

The width of a highway bridge depends upon the amount and character of the traffic which it must carry and to which it will be

Figure 12. Concrete Culvert, Town of West Bloomfield, Ontario County, New York. Designed by New York Highway Commission. Span 4 ft. Roadway 22 ft. Cost $375. Culvert has been built at an angle to the axis of the stream flow.

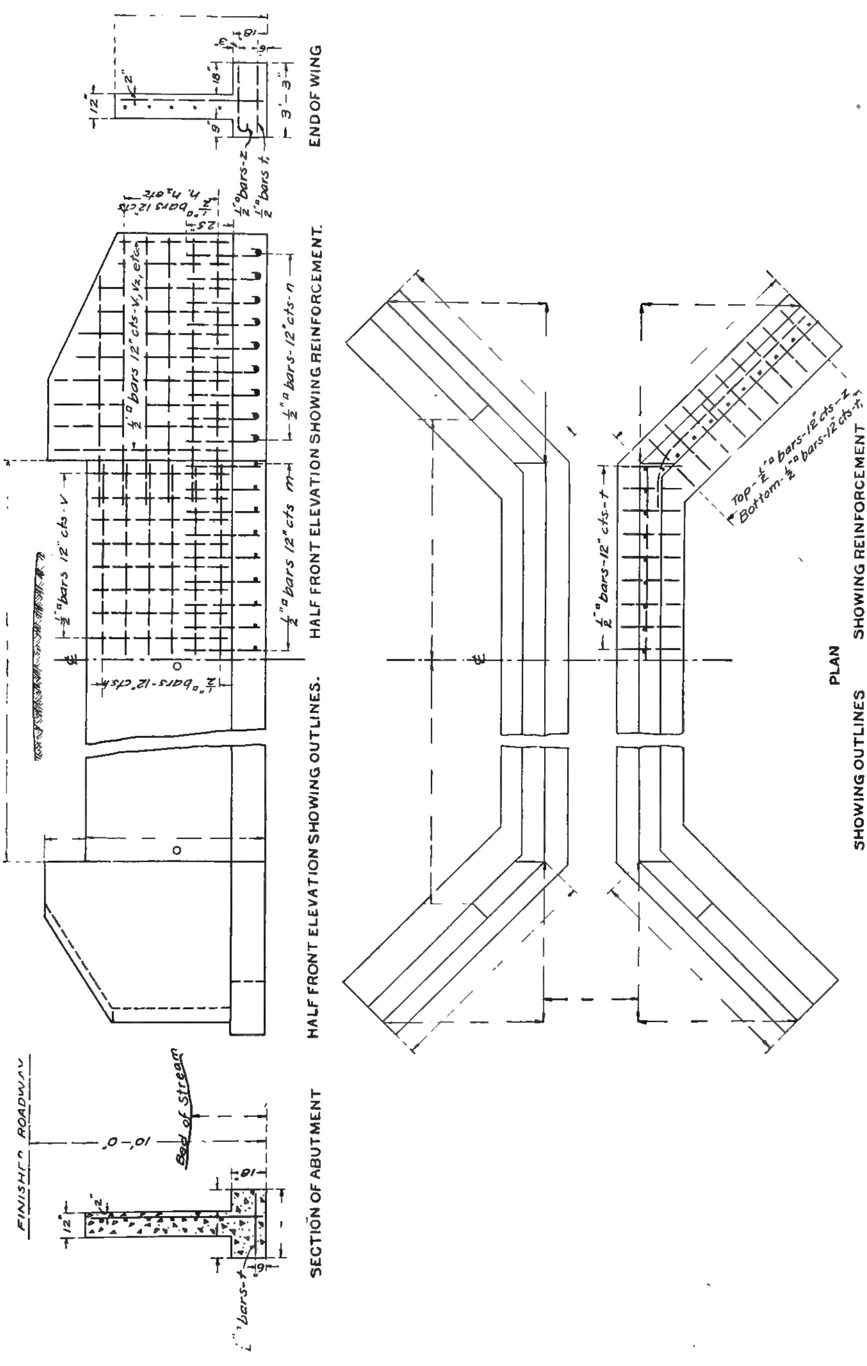

Figure 13. Concrete Sub-structure of 10 feet over all height. Designed by the Illinois Highway Commission.

subjected in the future. This question should be considered carefully by a community when constructing a bridge of such permanent material as concrete. While the designs show a standard width of 16 feet, this width may be increased to accommodate the traffic. In no case should a bridge be built with less than a 16 foot roadway.

While the designs are for plain concrete abutments, it may be found at times more economical to use reinforced abutments. Figure 13 shows a standard reinforced concrete sub-structure designed by the Illinois Highway Commission. This type of reinforced sub-structure is used where the wings can be swung nearly parallel to the axis of the roadway. No dimensions are given for the length of the wing walls nor base of the abutment for the reason, as has been previously stated, that these dimensions are influenced by the character of the stream banks. The following table gives size and length of steel reinforcement required.

Note—

Use two thicknesses of building paper between adjacent surfaces of substructure and superstructure.

In the elevation the wing is swung parallel with face of abutment to show reinforcement.

All exposed edges of wings to be beveled with ¾ inch triangular molding.

Place 3-inch tile drains in abutment walls one foot above ground line at abutment.

Concrete to be proportioned 1:2½:4.

Reinforcement to be round soft steel rods.

Bill of Material

Letter	No.	Size	Length
V	....	½″	....
V1	....	½″	....
V2	....	½″	....
V3	....	½″	....
H	....	½″	....
H	....	½″	....
M	....	½″	3′ 6″
N	....	½″	4′ 0″
T	....	½″	....
T1	....	½″	3′ 0″
Z	....	½″	3′ 6″

The reinforced abutment will contain a much smaller amount of concrete and will, therefore require considerably less excavation. However, the cost will be increased because of the cost of the steel and the additional work required in placing the steel and the concrete in the narrower space between forms. The plain concrete abutment is more simple in construction and under all ordinary conditions will be found more economical.

Slab Bridges

As has been previously stated, slab bridges consist either of flat slabs or of combined beams and slabs of concrete reinforced with steel. For spans 20 feet and less, flat slabs or slabs without beams are the most economical, the more simple of construction, and will therefore, be the only type considered in this book.

In the prairie country, the stream gradients are generally flat, the water course is crooked and the banks low, at least upon one side. For these water courses, where the head room is limited, the slab type of bridge or culvert is preferable to the arch. These streams will usually be out of their banks and flowing over road grades before using much head room, therefore, a waterway sufficient to take the ordinary flow will be entirely adequate.

In flat country the foundation is usually light soil, as rock seldom approaches near enough to the surface to found abutments upon it. Under these conditions the slab bridge which carries the load vertically upon the foundation is to be preferred to an arch bridge which carries the load at an angle. Moreover, a slab bridge is less liable to suffer damage due to any slight settlement of its abutments, while the least displacement of the abutment of an arch endangers its stability.

Forms

The forms for the reinforced slab bridge floor are so simple in construction that no detailed description is necessary. The important thing to remember is the enormous weight which the forms will be required to support. The floor slab for a 20-foot span with 16-foot roadway will weigh approximately 50 tons. The supporting

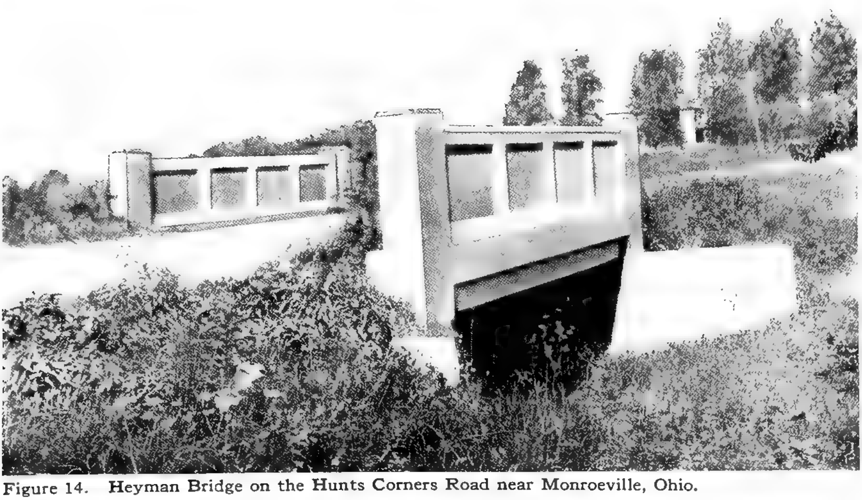

Figure 14. Heyman Bridge on the Hunts Corners Road near Monroeville, Ohio.

shores and lagging sustain this weight and must be designed accordingly. Where a muddy creek bottom is encountered, the shores must rest on a firm foundation so that no settlement will occur.

Abutments

The dimensions of the end and wing walls depend upon the value "H" or the height of the bridge floor above the top of the footing. The value of "H" is entirely independent of the span and is in-- fluenced by the local conditions existing at the site of the bridge. It depends upon the depth neccessary to secure a firm foundation and the amount of head room required to accommodate the stream flow. The footings must in all cases be carried to a foundation having sufficient bearing power, as described in the section on foundations, page 7.

Table 3 gives the dimensions of the end and wing walls for the varying values of "H." In all cases the length of the wing walls has been taken as equal to "H". The top of the wing wall is given a slope of one foot in every two feet, that is, for any value of "H", the height of the end section of the wing wall should be one-half of "H." The concrete for the abutments should be proportioned as previously described under "Abutments," page 13.

Bridge Seat

As indicated in Figure 17, two thicknesses of building paper should be placed between the adjacent surfaces of the abutment and the bridge floor. This prevents any bond between the sub-structure and superstructure, and gives a bridge floor with both ends free. Without such a precaution, the top of the abutment will be subjected to excessive strains due to the expansion and contraction of the bridge floor from temperature changes.

Figure 17 shows a design for a flat slab bridge of spans from 8 to 20 feet. The thickness of the floor slab required for the various spans to-

Figure 15. Concrete Bridge, Silver Lake Township, Martin Co., Minnesota. 20 foot span. 18-foot roadway Cost $734.

Table No. 3 To Accompany Table No. 4. Dimensions of Abutments and Amount of Materials

Note—H Depends on Location, not upon Span.

ABUTMENTS					SPAN							
END WALLS			WING WALLS									
H	B	C	L	G		8	10	12	14	16	18	20
5	2'– 0"	2'– 6"	5	2'–0"	Abutment	22.0	22.0	22.0	22.0	24.6	24.6	24.6
					Floors and Guard	7.4	9.9	12.4	16.0	21.1	25.1	29.4
					Cement	38.6	42.8	46.5	51.5	62.0	68.5	74.9
					Sand	13.3	14.7	15.8	17.5	21.0	22.8	24.7
					Gravel	26.6	29.4	31.6	35.0	42.0	45.6	49.4
6	2'– 5"	3'– 3"	6	2'–0"	Abutment	31.2	31.2	31.2	31.2	34.4	34.4	34.4
					Floors and Guard	7.4	9.9	12.4	16.0	21.1	25.1	29.4
					Cement	50.1	53.8	57.6	57.6	74.6	80.7	87.1
					Sand	17.7	18.9	20.0	21.7	25.5	27.4	29.3
					Gravel	35.4	37.8	40.0	43.4	51.0	54.8	58.6
7	2'–10"	3'–10"	7	2'–0"	Abutment	41.0	41.0	41.0	41.0	44.8	44.8	44.8
					Floors and Guard	7.4	9.9	12.4	16.0	21.1	25.1	29.4
					Cement	62.3	66.0	69.8	69.8	87.6	93.7	100.1
					Sand	22.3	23.4	24.6	26.2	30.3	32.2	34.1
					Gravel	44.6	46.8	49.2	52.4	60.6	64.4	68.2
8	3'– 2"	4'– 2"	8	2'–6"	Abutment	51.0	51.0	51.0	51.0	55.2	55.2	55.2
					Floors and Guard	7.4	9.9	12.4	16.0	21.1	25.1	29.4
					Cement	74.9	78.6	82.3	82.4	100.6	106.7	113.1
					Sand	26.8	28.0	29.2	30.8	35.1	36.9	38.9
					Gravel	53.6	56.0	58.4	61.6	70.2	73.8	77.8
9	3'– 7"	4'–10"	9	2'–6"	Abutment	64.6	64.6	64.6	64.6	69.4	69.4	69.4
					Floors and Guard	7.4	9.9	12.4	16.0	21.1	25.1	29.4
					Cement	91.8	95.5	99.3	99.3	118.3	124.4	130.8
					Sand	33.1	34.3	35.4	37.1	41.6	43.5	45.4
					Gravel	66.2	68.6	70.8	74.2	83.2	87.0	90.8
10	4'– 0"	5'– 6"	10	2'–6"	Abutment	80.4	80.4	80.4	80.4	85.4	85.4	85.4
					Floors and Guard	7.4	9.9	12.4	16.0	21.1	25.1	29.4
					Cement	111.6	115.3	119.1	119.1	138.3	144.4	150.8
					Sand	40.4	41.5	42.7	44.3	49.0	50.8	52.8
					Gravel	80.8	83.0	85.4	88.6	98.0	101.6	105.6
					Top of Abutment S=12"					Top of Abutment S=18"		

Note—All quantities in above table are given in cu. yds. except cement which is given in bbls.
Concrete—For Floor Slab 1:2:4. For Abutments 1:2½:5.

Table No. 4, Reinforcement for Flat Slab Bridge, 16-Ft. Roadway, Computed for 24-Ton Roller

Span	Slab Thickness	Depth of Concrete Below Steel	FLOOR SLAB.								GUARD RAILS (Both)								Diagonal Rods
			TENSION STEEL				TEMPERATURE STEEL				HORIZONTAL				VERTICAL				
			No.	Size	Spacing	Length	No.	Size	Spacing	Length	No.	Size	Spacing	Length	No.	Size	Spacing	Length	No.
8′	9 ″	1 ″	43	5/8″	5 ″	11′	9	5/8″	12″	18′	6	1/2″	15″	9′	10	1/2″	24″	3′-6″	20
10′	10 1/2″	1 1/4″	33	3/4″	6 1/2″	13′	7	3/4″	18″	18′	6	1/2″	15″	11′	12	1/2″	24″	3′-6″	24
12′	11 1/2″	1 1/4″	39	3/4″	5 1/2″	15′	8	3/4″	18″	18′	6	1/2″	15″	13′	14	1/2″	24″	3′-6″	28
14′	13 1/2″	1 1/2″	43	3/4″	5 ″	18′	12	3/4″	15″	18′	6	1/2″	15″	15′	16	1/2″	24″	3′-6″	32
16′	15 1/2″	1 1/2″	47	3/4″	4 1/2″	20′	17	3/4″	12″	18′	6	1/2″	15″	17′	18	1/2″	24″	3′-6″	36
18′	17 ″	1 3/4″	31	1 ″	7 ″	23′	12	1 ″	18″	18′	6	1/2″	15″	19′	20	1/2″	24″	3′-6″	40
20′	18 1/2″	1 3/4″	33	1 ″	6 1/2″	25′	21	1 ″	12″	18′	6	1/2″	15″	21′	22	1/2″	24″	3′-6″	44

Note:—

Round soft steel used for all reinforcement

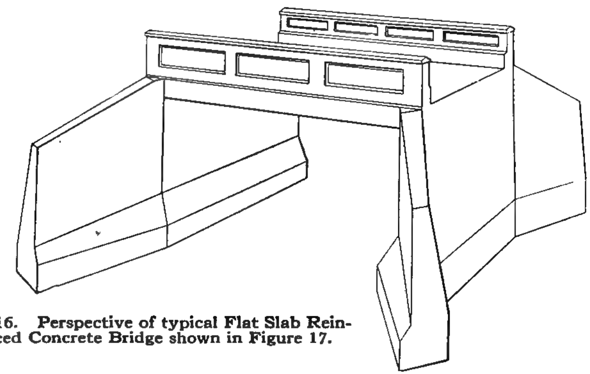

Figure 16. Perspective of typical Flat Slab Reinforced Concrete Bridge shown in Figure 17.

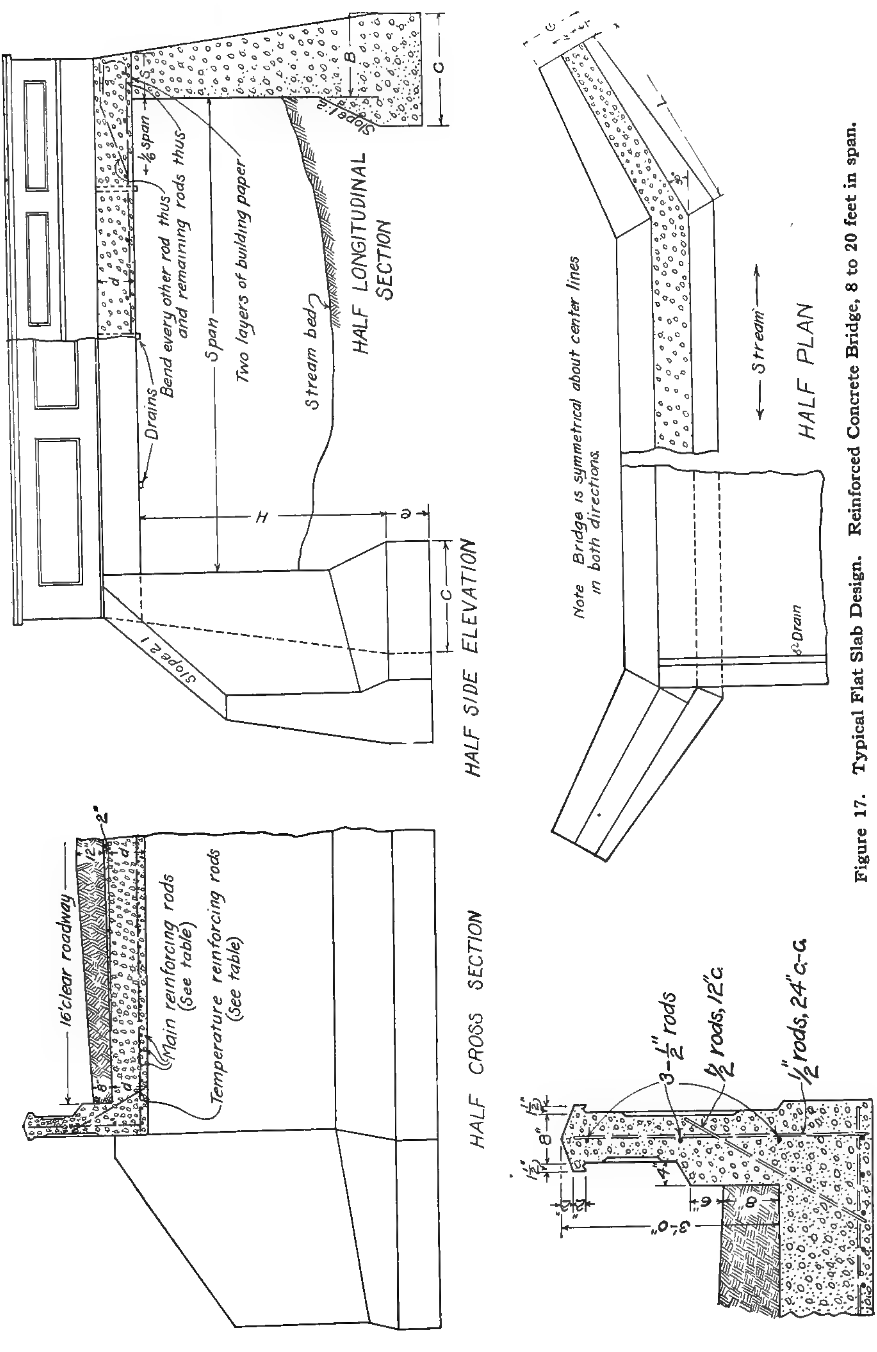

Figure 17. Typical Flat Slab Design. Reinforced Concrete Bridge, 8 to 20 feet in span.

Bridge Slab

gether with the size and spacing of the reinforcing rods will be found in Table 4. It should be noted that the floor slab is given a 2-inch pitch at the center which must be added to the tabulated thickness of the slab. This facilitates the drainage of the roadbed for which drains should be provided as shown in Figure 17.

These bridges are designed to carry a fill of from 8 to 12 inches. The practice of using a concrete floor without a covering of earth or other paving material is not to be recommended. The road material should be carried continously across the bridge or culvert, thus helping to distribute the load and preventing wear and excessive vibration.

Proportions

The concrete for the slab should be proportioned 1 sack of Portland cement, 2 cubic feet of sand and 4 cubic feet of screened gravel or crushed stone. The materials must be selected and mixed as described in section under aggregates on page 11.

Placing of Concrete

In depositing concrete around the steel, great care must be taken, as before stated, to see that the steel is not disarranged and that it is in position as shown by the design. This will be accomplished much more easily if the steel has been thoroughly and carefully wired together.

The concrete should be placed for the full thickness of the slab and in one continuous operation. The depth of concrete below the steel must in all cases be as shown in Table 4 for the various spans.

Figure 18. Concrete Arch Bridge, Marion County, Indiana. 20-foot span; cost $1,500. This bridge is of monolithic concrete construction but marked in imitation of stone masonry.

Arch Bridges

Where the stream banks are steep, giving plenty of head room, and where the soil is clay, gravel or rock, affording a good foundation, the arch type of bridge or culvert is preferable to the flat slab construction. The arch type gives a pleasing artistic appearance, harmonizing agreeably with the character of the country in which this type of bridge construction can be used.

The arch places a heavier load upon its foundation than does the flat slab bridge, but where the proper foundation is secured, this heavier load is an advantage when the effect of the moving loads is considered. The stability of the arch is not affected by an increase in the moving load as the slab bridge would be. However, the least settlement of the abutments endangers the stability of the arch. In all cases the abutments must have a sufficient spread at the base, so that the load on the foundation will not exceed the safe unit load as given in table under "Foundations," page 8.

Forms

Substantial centers or forms must be provided for concrete arches and should be of good quality lumber as previously described. Figure 21 shows in detail, method of constructing the arch form. The ribs as shown in Figure 21 should be spaced every four feet supporting the two-inch by six-inch lagging. These ribs are supported on wooden posts as shown, which must be placed upon a firm foundation. The wedges shown in the figure should be of hardwood and smooth finished so that they may easily be driven without shock, but there must be no danger of them slipping. The safe removal of the centering depends upon the proper driving of these wedges. The spandrel and guard rail forms may be built in place at the same time that the arch ring centering is placed. To prevent the concrete sticking to the forms they should be treated as previously suggested.

When ready to strike the centers, the wedges under the crown of the arch should first be knocked out, leaving those at the springing line until the last. These wedges are essential in order that no unequal strains may be placed upon the arch during the removal of the forms and are therefore the most important item in the construction of the arch centering.

Time to Remove Forms

The arch centers must be left in place until the concrete has hardened thoroughly and the structure is capable of withstanding all loads which may be placed upon it. In no case should these supports be removed in less than 28 days and should remain much longer if the weather has been unfavorable for the hardening of concrete.

Figure 19 shows a design for a plain concrete semi-circular arc bridge varying in span from 10 to 20 feet. The thickness of the arch

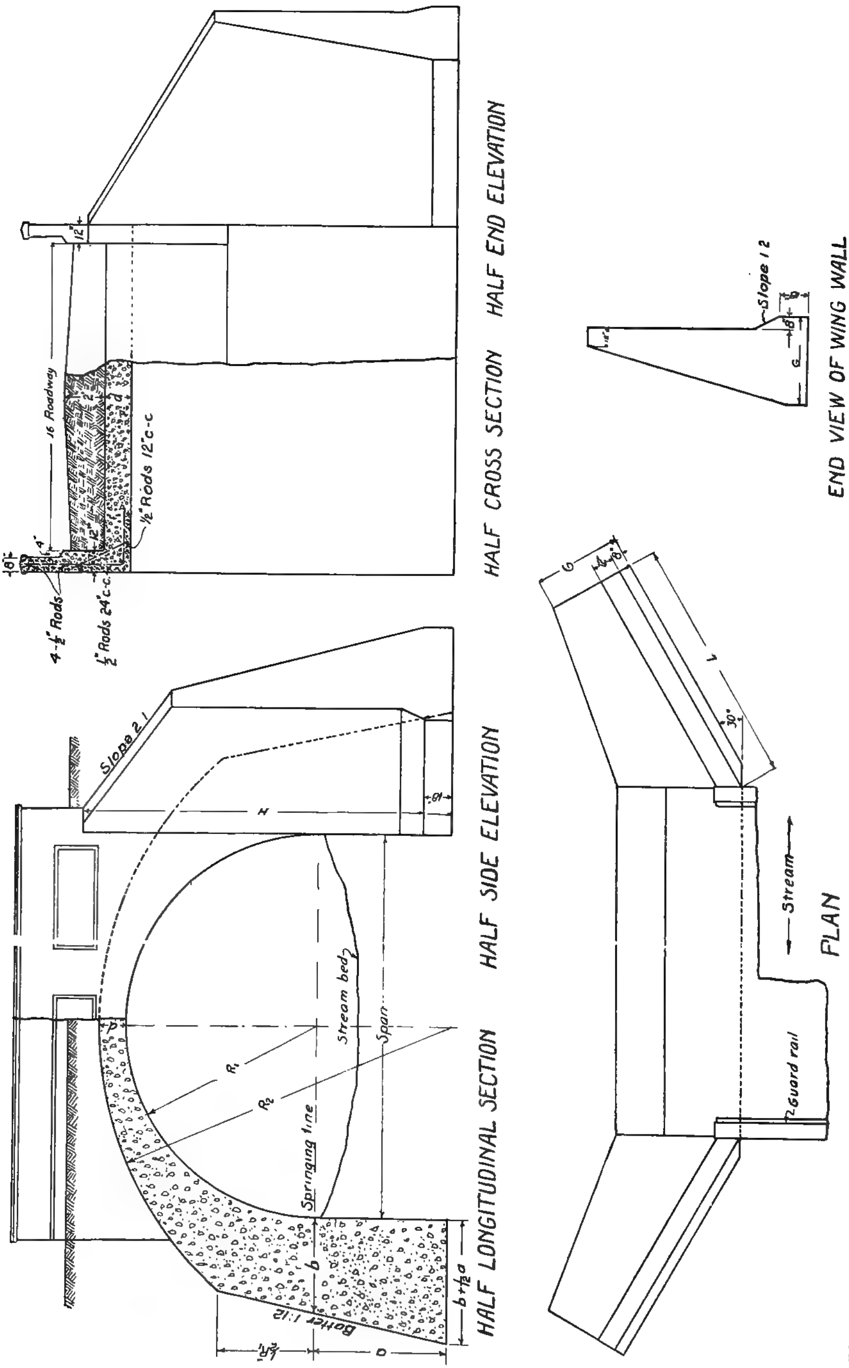

Figure 19. Typical Design. Plain Concrete Arch Bridge, 10 to 20 feet in span.

Conditions Required for Stability

ring at the crown and springing line, and amount of reinforcement required for the guard rail is given in Table 5 while Table 6 gives the dimensions of the wing walls and amount of materials required for the various spans. In Table 6, we have assumed a definite value for "a," or the depth of the abutment to the foundation, in order to figure quantities. This value of "a" will be governed entirely by the depth necessary to secure a good foundation, but in going to a greater depth, care must be taken to see that the abutments are stable. In order to secure the proper stability, the width of the base of the abutment must always exceed $\frac{2}{3}$ of the height, that is, the values given in column ("b + 1/12 a") in the table must always be greater than $\frac{2}{3}$"a." If local conditions are such that this does not hold true, the value of "b + 1/12 a" must be increased to comply with this rule.

Proportions for Arch Ring

The concrete for the arch ring should be carefully mixed as described in the sections under "Aggregates," page 11 and should be proportioned 1 sack of Portland cement, 2 cubic feet of sand and 4 cubic feet of screened gravel or crushed stone.

Placing of Concrete

The concrete for the arch ring should be placed in one continuous operation. Where it is impossible to place the concrete for the arch in a single day, the arch ring should be divided into either longitudinal or transverse sections such that each section will constitute a day's work. Both methods have been used quite extensively.

However, most engineers believe it to be better practice to build the arch as a series of transverse courses beginning at the springing line. The advantages of this method are that the plane of weakness will be at right

Figure 20. Arch Bridge, Marion County, Indiana. 8-foot span; 2-foot rise; 18-foot roadway. Cost $550.

Table No. 5, Plain Concrete Arch Bridge, 16-Foot Roadway

Span Ft.	Crown d	Spring Line b	R1	R2	b† 1 12 a	Batter	GUARD RAIL Horizontal No.	Size	Spacing	Length	REINFORCEMENT Vertical No.	Size	Spacing	Length	Diagonal Rods
10	12″	3′– 6″	5′–0″	11′ 9″	The value of "b+1/12 a" must be greater than ⅔a to insure stability of abutment	1:12 in all cases	8	½″	12″	13′	16	½″	24″	5′	26
12	13″	3′ 10″	6′–0″	13′ 6″			8	½″	12″	15′	18	½″	24″	5′	30
14	14″	4′– 1″	7′–0″	14′ 8″			8	½″	12″	18′	22	½″	24″	5′	36
16	15″	4′– 5″	8′–0″	16′ 3″			8	½″	12″	21′	24	½″	24″	5′	40
18	16″	4′– 8″	9′–0″	17′ 8″			8	½″	12″	22′	28	½″	24″	5′	44
20	17″	5′– 0″	10′–0″	18′ 4″			8	½″	12″	25′	30	½″	24″	5′	50

Table No. 6 to Accompany Table No. 5, Plain Concrete Arch Bridge, 16-Foot Roadway Dimensions of Abutments and Amount of Materials

Span	a	H	L	G	Concrete: Arch Ring and Guard Rail Cu. Yds.	Concrete: Abutments Cu. Yds.	Amount of Materials: Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yd.
10	To be carried to a firm foundation. Assumed as 3′ to figure quantities.	10′–0″	7′–0″	2′–10″	33.1	31.5	89.0	29.7	59.4
12		11′–0″	8′–0″	3′– 1″	41.3	40.2	112.1	37.5	75.0
14		12′–0″	9′–0″	3′– 4″	48.6	53.6	139.9	47.0	94.0
16		13′–0″	10′–0″	3′– 6″	63.4	61.7	172.2	57.5	115.0
18		14′–6″	11′–6″	3′– 8″	77.3	77.0	212.2	71.0	142.0
20		15′–6″	12′–6″	3′–11″	83.6	85.3	232.0	77.7	155.4

Concrete:
Arch Ring 1:2:4.
Abutments 1:2½:5.

Steel:
Round, Soft Steel Rods

angles to the line of pressure, and that unequal loading and consequent settlement has less tendency to separate one section from another. In building the arch as a series of transverse courses, the concrete should be deposited equally on both sides of the arch. This keeps the loading symmetrical on the forms and prevents unequal settlement. In no instance should a joint be made at the crown.

Earth Fill

Since the roadway must not deviate greatly from a horizontal line, a considerable amount of filling is required above the arch ring. This filling should be at least 12 inches in depth at the crown in order to form a cushion and absorb the shock due to passing loads. The standard width of roadway, 16 feet, has been shown in these designs, but this width should, if necessary, be increased to accommodate the traffic.

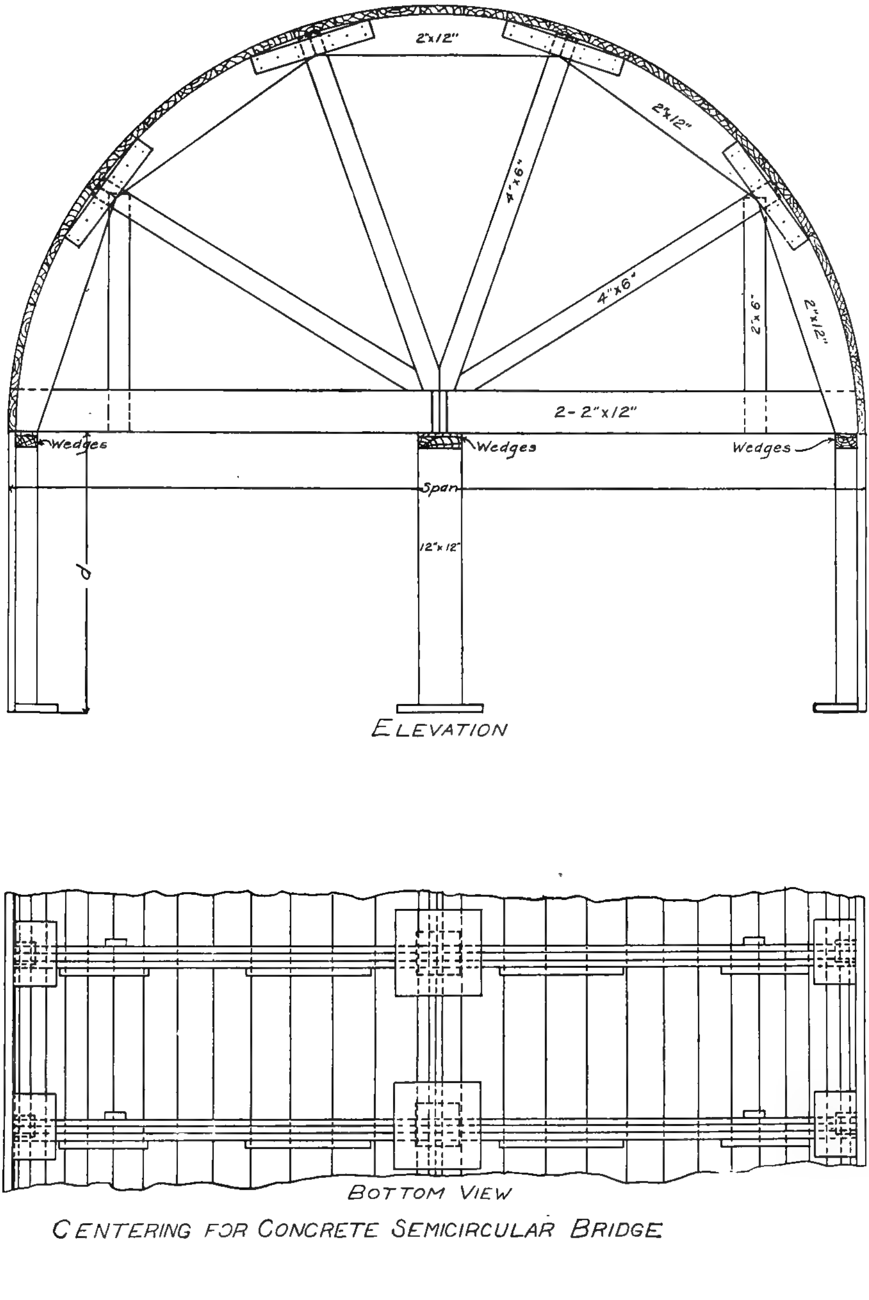

Figure 21. Centering for Concrete Arch Bridges and Culverts.

Culverts

The providing of a satisfactory and economical crossing of the small stream water courses and ditches is not the least of the Highway Commissioner's trouble. Many of these ditches are spanned by wooden or other temporary culverts requiring constant attention and frequently are in a condition to invite accidents. The continual annoyance and expense of repairs can easily be avoided by building concrete culverts.

The angle at which a culvert crosses the road should be considered carefully. As far as possible, it should be placed in the direction of the flow of the water. In most of the locations, culverts are placed at right angles to the roadway, although the streams seldom cross the roads at right angles. Failure to place culverts across roadways in the direction of the stream flow, often causes clogging which results in washouts thus making repairs necessary.

Angle Across Roadway

The length of the culvert will depend upon the width of roadway and the depth of fill on top of the culvert. Where there is a heavy fill on the culvert it must be of sufficient length to accommodate the slope of the fill. The natural slope of any earth fill can generally be taken as $1\frac{1}{2}$ to 1, that is, for every 1 foot in height, the horizontal distance is $1\frac{1}{2}$ feet; therefore, a 10-foot fill with 16-foot roadway would require a culvert 46 feet in length.

Concrete culvert construction is essentially the same as that used for bridges. Likewise the concrete culvert may be built either in arch form or as a simple reinforced flat top concrete box.

Figure 22. Concrete Culvert, Milo, Yates County, New York. Designed by New York Highway Commission. Culvert Head Walls 40 feet long, 16 feet high; opening 5 feet x 6 feet. Built with town labor at a cost of $636.

Box Culvert

In a flat country and under shallow fills, the box culvert has a great advantage over the arch culvert, requiring much less head room and therefore less excavation. The form work for this type of culvert is much simpler and the cost of construction correspondingly lowered.

Forms

The forms for this type of culvert are very simple and no special instructions are necessary. The face of the forms should be made of 2 x 6 lumber, dressed on one side and two edges. The cross section view in Figure 25 shows the supporting bents which should be spaced every three feet and be built of 2 x 4 lumber. In order that the forms may be removed easily, the upper brace is held and fitted in place by wedges. When ready to remove forms, these wedges are knocked out and the supports for the top of the culvert dropped down, thus permitting the easy removal of the forms. The typical design for the forms of the wing walls is shown in Figure 11, page 19.

Floor and Wing Wall

Table 7 gives the dimensions of the wing walls and amount of materials required for abutments and floor of the culvert. Culverts may be built with or without floor according to the stability of the soil and local conditions. The smooth waterway obtained by using concrete floors increases the capacity of the culvert and prevents the clogging of the waterway by drift. This floor will also prevent erosion of the stream bed and the undermining of the foundation. It is advisable to provide joints between the floor and sides of the culvert, thus protecting the floor against cracking should settlement occur. To prevent erosion under floor an apron, as shown in the drawing, should in all cases be carried to a depth equal to the bottom of the footing. The floor is shown as carried out to the end of the wing walls. This improves the smooth waterway and is an added protection to the wing. However, if so desired this floor may be omitted.

Figure 23. A double culvert built in Lee County, Iowa, each opening being 42 inches in diameter and 20 feet long. The wing walls are 20 feet long, 8 feet high and 10 inches thick. This was built with the Merrillat Culvert Core Company's form at a totol cost of $112.

Table No. 8, Flat Top Culvert, 2-Foot Fill, Computed for 24-Ton Roller

Span	Height	Slab Thickness "d"	SLAB					Side Walls		Materials per Foot of Length Exclusive of Wing Walls				
			Concrete Below Steel	Reinforcement										
				Tension		Temperature								
				Size	Spacing	Size	Spacing	C	e	Steel lbs.	Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3′–0″	3′–0″	6 ″	1 ″	½″	6 ″	½″	12″	1′– 8″	To extend to firm foundation in all cases. Assumed as 18″ to figure quantities.	8.0	.65	.835	.30	.60
3′–6″	3′–6″	6½″	1 ″	½″	5½″	½″	12″	1′–10″		9.3	.77	.99	.35	.71
4′–0″	4′–0″	7 ″	1 ″	½″	5 ″	½″	12″	2′– 0″		12.2	.89	1.15	.41	.82
4′–6″	4′–6″	7½″	1 ″	½″	4½″	½″	12″	2′–2″		14.6	.97	1.25	.45	.89
5′–0″	5′–0″	8 ″	1 ″	½″	4 ″	½″	12″	2′– 5″		17.3	1.08	1.39	.50	.99
5′–6″	5′–6″	8½″	1 ″	½″	4 ″	½″	12″	2′– 7″		17.3	1.32	1.70	.61	1.21
6′–0″	6′–0″	8½″	1 ″	⅝″	6 ″	⅝″	12″	2′– 9″		20.6	1.49	1.91	.68	1.37
7′–0″	7′–0″	9½″	1¼″	⅝″	5½″	⅝″	12″	3′– 2″		27.0	1.79	2.30	.82	1.65
8′–0″	8′–0″	10 ″	1¼″	⅝″	5 ″	⅝″	12″	3′– 6″		32.0	2.20	2.83	1.01	2.02

Concrete: For Slab 1:2:4. For Side Walls 1:2½:5. Steel: Soft round rods.

Table No. 9, Flat Top Culvert, 6-Foot Fill, Computed for 24-Ton Roller

Span	Height	Slab Thickness "d"	SLAB					Side Walls		Materials per Foot of Length Exclusive of Wing Walls				
			Concrete Below Steel	Reinforcement										
				Tension		Temperature								
				Size	Spacing	Size	Spacing	C	e	Steel Lbs.	Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3′–0″	3′–0″	6½″	1 ″	½″	5½″	½″	12″	1′– 8″	18″ to figure quantities.	9.3	.66	.85	.30	.60
3′–6″	3′–6″	7 ″	1 ″	½″	5 ″	½″	12″	1′–10″		10.8	.78	1.03	.36	.71
4′–0″	4′–0″	7½″	1 ″	½″	4½″	½″	12″	2′– 0″		13.5	.89	1.15	.41	.82

4'-6"	4'-[illegible]"	8 "	1 "	½"	4 "	½"	12"	2'- 2"	To extend to a firm foundation in all cases. Assumed as	15.6	.98	1.27	.45	.90
5'-0"	5'-0"	8½"	1 "	⅝"	6 "	⅝"	12"	2'- 5"		17.8	1.09	1.41	.50	1.00
5'-6"	5'-6"	9 "	1¼"	⅝"	5½"	⅝"	12"	2'- 7"		22.0	1.33	1.72	.61	1.22
6'-0"	6'-0"	9½"	1¼"	⅝"	5 "	⅝"	12"	2'- 9"		26.2	1.51	1.95	.70	1.39
7'-0"	7'-0"	11 "	1¼"	⅝"	4½"	⅝"	12"	3'- 2"		32.0	1.83	2.36	.84	1.68
8'-0"	8'-0"	12 "	1¼"	¾"	6 "	¾"	12"	3'- 6"		38.0	2.20	2.92	1.04	2.08

Concrete: For Slab 1:2:4. Side Walls 1:2½:5. Steel: Soft round rods.

Table No. 10, Flat Top Culvert, 10-Foot Fill, Computed for 24-Ton Roller

Span	Height	Slab Thickness	Concrete Below Steel	SLAB Reinforcement Tension Size	Tension Spacing	Temperature Size	Temperature Spacing	Side Walls C	Side Walls e	Materials per Foot of Length Exclusive of Wing Walls: Steel Lbs.	Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3'-0"	3'-0"	6½"	1 "	½"	5½"	½"	12"	1'- 8"	To extend to a firm foundation in all cases. Assumed as 18" to figure quantities.	9.3	.66	.85	.30	.61
3'-6"	3'-6"	7 "	1 "	½"	5 "	½"	12"	1'-10"		10.8	.78	1.03	.35	.72
4'-0"	4'-0"	7½"	1 "	½"	4½"	½"	12"	2'- 0"		13.5	.90	1.16	.41	.83
4'-6"	4'-6"	8½"	1 "	⅝"	6 "	⅝"	12"	2'- 2"		15.6	.99	1.28	.45	.91
5'-0"	5'-0"	9 "	1¼"	⅝"	5½"	⅝"	12"	2'- 5"		20.8	1.11	1.44	.51	1.02
5'-6"	5'-6"	9½"	1¼"	⅝"	5 "	⅝"	12"	2'- 7"		23.9	1.34	1.73	.[illegible]2	1.23
6'-0"	6'-0"	10 "	1¼"	⅝"	5 "	⅝"	12"	2'- 9"		23.9	1.53	1.98	.70	1.40
7'-0"	7'-0"	11½"	1¼"	⅝"	4 "	⅝"	12"	3'- 2"		35.4	1.85	2.39	.85	1.70
8'-0"	8'-0"	13 "	1½"	¾"	5½"	¾"	12"	3'- 6"		41.0	2.29	2.96	1.05	2.10

Concrete: For Slab 1:2:4. For Side Walls 1:2½:5. Steel: Soft round rods,

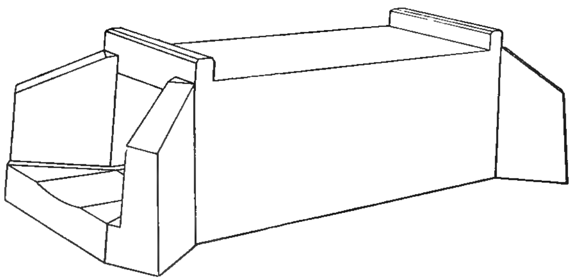

Figure 24. Perspective of Typical Reinforced Concrete Box Culvert shown in Figure 25.

The lengths of the wing walls have been given as equal to the span in every case. This length will undoubtedly be governed to some extent by local conditions, but it will be found that the lengths assumed in Table 7 will be applicable in all ordinary instances.

Culvert Slab

Figure 25 shows a design for a box culvert varying from 3 to 8 feet in span. The thickness of the side walls and top together with amount of steel reinforcing required, can be obtained from Tables 8, 9, 10. These tables also give the amount of materials per linear foot of culvert. Where the culvert is to be placed at the bottom of a fill, it must be designed to sustain the additional load due to the weight of the earth fill, and these tables have, therefore, been figured for two, six and ten foot fills. The tables appear on pages 36 and 37.

Concrete for the culvert slab should be proportioned 1:2:4, that for the sides, wing walls and floor should be 1:2½:5.

Table No. 7 to be Used with Tables Nos. 8, 9 and 10.
Dimensions for Wing Walls—Flat Top Culvert

Span	Height = Span + Floor Thickness	L = Span	G	Depth of Apron	Amount of Materials, Including Apron, Guard Rail, and Floor Between Wing Walls			
					Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3′-0″	3′- 6½″	3′-0″	1′- 8″	Minimum depths 18″. Should be carried to bottom of footings in all cases.	3.5	4.7	1.6	3.2
3′-6″	4′- 1 ″	3′-6″	1′-10″		4.3	5.4	2.0	4.0
4′-0″	4′- 7½″	4′-0″	2′- 0″		5.8	7.2	2.7	5.4
4′-6″	5′- 2½″	4′-6″	2′- 0″		7.1	8.9	3.3	6.6
5′-0″	5′- 9 ″	5′-0″	2′- 3″		8.6	10.7	4.0	8.0
5′-6″	6′- 3½″	5′-6″	2′- 3″		10.4	13.0	4.8	9.6
6′-0″	6′-10 ″	6′-0″	2′- 6″		12.8	16.0	5.9	11.8
7′-0″	7′-11½″	7′-0″	2′- 9″		17.4	21.8	8.0	16.0
8′-0″	9′- 1 ″	8′-0″	3′- 0″		25.6	32.0	11.8	23.6

Concrete:
1:2½:5

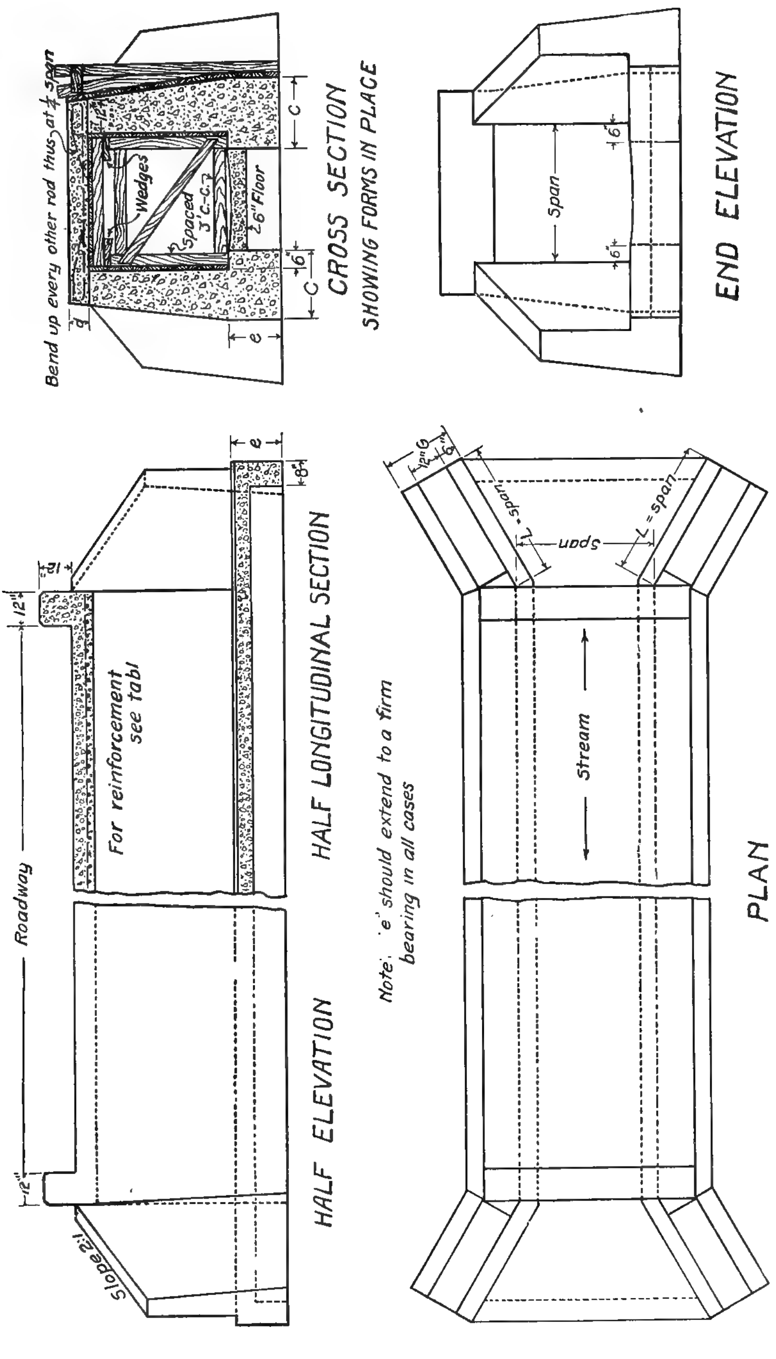

Figure 25. Typical Design. Reinforced Box Culvert, 3 to 10 feet in span.

When the area of waterway required is small, that is, under 36 inches in diameter, it is more economical to build a concrete pipe culvert. No culvert of this class should be constructed having a smaller opening than 15 inches. These culverts are not complete without head walls as shown in the other designs.

Collapsible Wood Forms for Circular Culvert

Figure 27 shows an adjustable, collapsible wood form which can be very economically used for the construction of culverts from 18 in. to 48 in. in diameter. It was originally designed by F. H. Meliza, Farmer City, Ill., and was mentioned in the Illinois Highway Commission reports for 1907 and in a bulletin on highway improvement by W. S. Gearhart, Highway Engineer of Kansas, which was issued by the Kansas State Agricultural College.

This form is constructed of two by four's beveled and strung on wires as shown in the figure. The number of staves to be used, varying with the size of the culvert are placed side by side with a wire drawn through each end of the stave as shown. The form is then rolled around a circular head size of the proposed culvert and wire bands are tied tightly around it on the outside. Wedges are then driven as shown in Figure 27 to hold the staves firmly in position. After the culvert has been built the wedges are removed, and the circular heads knocked in; the staves will then collapse and are easily removed. This form can be used over and over again and Mr. Gearheart states that its cost should not exceed $15.00 or $20.00.

Figure 26. Reinforced Concrete Arch Bridge, Iroquois, South Dakota, 20-foot Span, 18-foot roadway. Designed by Missouri Valley Engineering Company, R. S. Warner, Contractor.

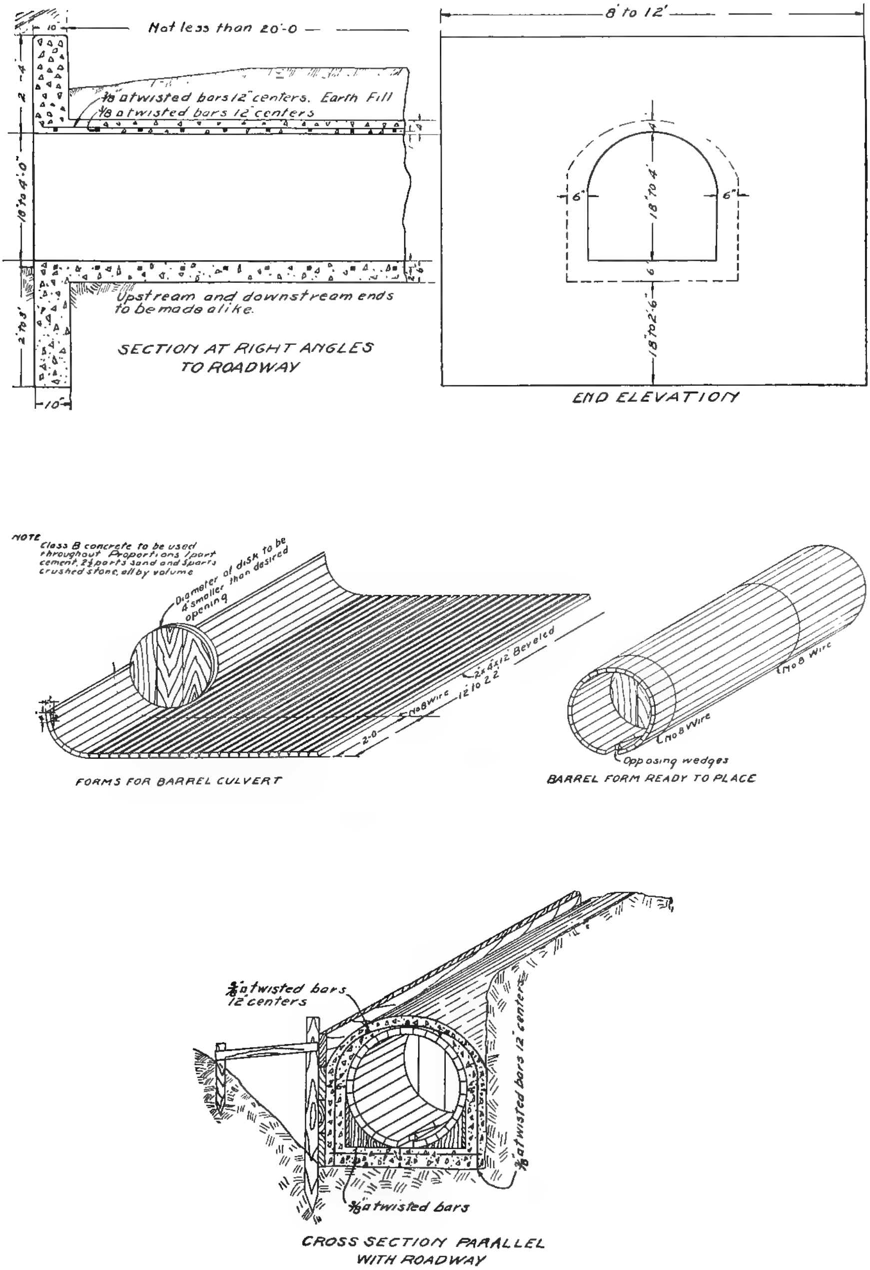

Figure 27. Plan for a collapsible, adjustable wood form for the construction of concrete culverts from 18 inches to 48 inches in diameter.

Plain Arch Culverts

The construction of arch culverts is essentially the same as for arch bridges. The arch culvert has the same advantages and disadvantages, when compared with the box culvert, as has the arch bridge when compared with the flat slab bridge. This type can be used only where there is plenty of head room or under a heavy fill; and where a suitable foundation can be obtained.

Figure 28. Plain Concrete Arch, 6-foot span, McLean Co., Illinois.

Forms

The forms for the arch culvert are similar to those required for an arch bridge and therefore, the centering as shown in Figure 21 is also applicable to the arch culverts. In the smaller spans it will not be necessary to provide wedges as shown for the larger sizes. However, care must be taken in striking the centers to see that no unusual strains are placed on the arch ring. The concrete for the footings and floor in the stream bed should be deposited first and the forms for the arch and sides can be erected on this concrete. The forms for the wing walls should be constructed as shown in detail in Figure 11, page 19.

Tables of Dimension

Figure 29 shows a design for plain arch culverts from 3 to 10 feet in diameter. The thickness of arch at crown and springing line for the various spans together with amount of materials required per linear foot of culvert are given in Table 11. Table 12 gives the dimensions of the wing walls and amount of materials required for abutments and floor of the culvert between the wing walls.

Conditions Required for Stability

The distance "h" or the height of the sides of the culvert from the top of the footing to the springing line, has been given a definite value in the tables. This value of "h" can, however, be governed to a certain extent by the area of waterway required, and may be varied to suit conditions. This variation in the value of "h" is limited for the reason that "h" must never exceed 1½ times the

thickness of the side walls at the top of the footing. If "h" exceeds this limit in height, the stability of the structure will be endangered. The sides of the culvert have been given a batter of 1 in 12 and a spread footing provided. This footing should be carried to a firm foundation at all times.

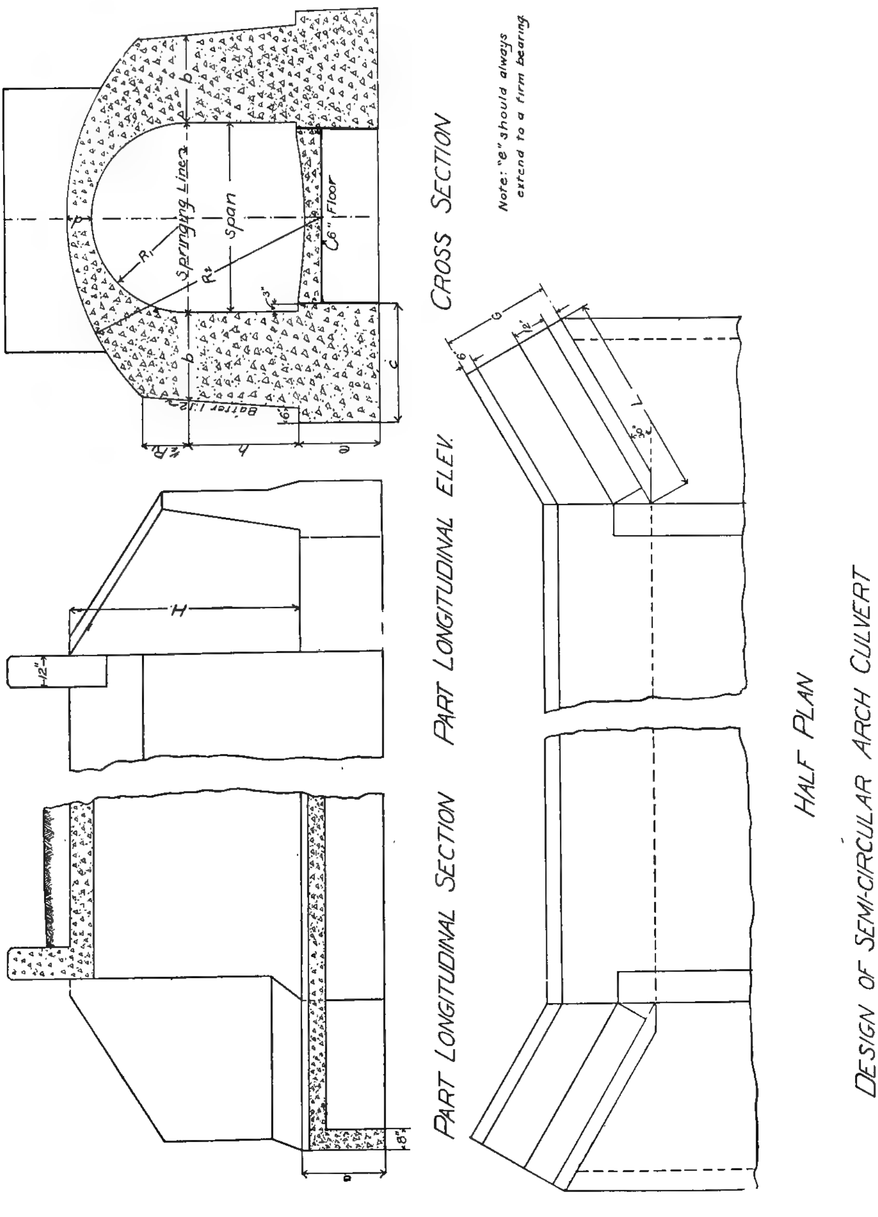

Figure 29. Typical Design. Plain Concrete Arch Culvert, 3 to 10 feet in span.

The concrete for an arch culvert should be placed in the same way and manner as described for an arch bridge. The arch ring should be deposited in one day where possible. If impossible to complete the arch

Table No. 11, Plain Concrete Arch Culvert

Span	Crown d	Springing Line b	R1	h	C	e	Materials Per Foot at Length: Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3′	6″	2′- 5″	1′-6″	2′-0″	3′- 4″	To extend to a firm foundation in all cases. Assumed as 18″ to figure quantities.	1.13	1.5	.52	1.04
3′-6″	6″	2′- 7″	1′-9″	2′-0″	3′- 6″		1.27	1.7	.58	1.16
4′-0″	6½″	2′- 8″	2′-0″	2′-6″	3′- 8″		1.41	1.8	.65	1.30
4′-6″	7 ″	2′- 8″	2′-3″	2′-6″	3′- 8″		1.50	2.0	.69	1.38
5′-0″	7½″	2′- 9″	2′-6″	3′-0″	3′- 9″		1.59	2.1	.73	1.46
5′-6″	8 ″	2′- 9″	2′-9″	3′-0″	3′- 9″		1.71	2.3	.79	1.58
6′-0″	8½″	2′-10″	3′-0″	3′-0″	3′-10″		1.93	2.6	.89	1.78
7′-0″	9 ″	3′- 0″	3′-6″	3′-6″	4′- 0″		2.32	3.1	1.07	2.14
8′-0″	10 ″	3′- 2″	4′-0″	4′-0″	4′- 3″		2.72	3.7	1.25	2.50

Concrete:
Arch Ring 1:2:4.
Abutments 1:2½:5.

in one day, it should be divided into transverse sections as previously described and each section taken as a day's work. In no case should a joint be made at the crown. The concrete for the arch culvert should be proportioned same as that for the arch bridge.

Table No. 11 to Accompany Table No. 12, Plain Concrete Arch Culvert Dimensions of Wing Walls and Amount of Materials Including Guard Rails Floor and Apron

Span	Height H	L	G	Concrete Cu. Yds.	Cement Bbls.	Sand Cu. Yds.	Gravel Cu. Yds.
3′	4′– 0″	3′–0″	2′–0″	3.8	4.72	1.75	3.50
3′–6″	4′– 3″	3′–6″	2′–0″	4.2	5.21	1.93	3.86
4′–0″	5′– 0″	4′–0″	2′–2″	6.9	8.55	3.18	6.36
4′–6″	5′– 7″	4′–6″	2′–4″	8.8	10.91	4.05	8.10
5′–0″	6′– 1″	4′–6″	2′–6″	10.2	12.64	4.69	9.38
5′–6″	6′– 5″	5′–0″	2′–7″	11.1	13.77	5.11	10.22
6′–0″	6′– 8″	5′–0″	2′–9″	12.8	15.87	5.88	11.76
7′–0″	7′– 9″	5′–6″	3′–0″	14.3	17.73	6.57	13.15
8′–0″	8′–10″	6′–0″	3′–5″	18.3	22.70	8.43	16.86

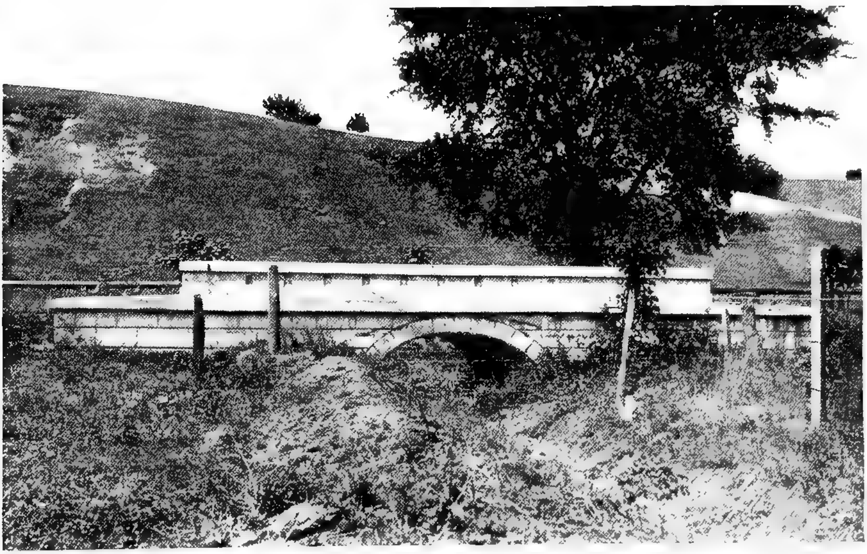

Figure 30. Concrete Arch Culvert, Marion Co., Indiana. 6-foot span; 3½-foot rise; 18-foot roadway. Cost $700. This bridge is of monolithic construction marked in block form.

Standard Plans of State Highway Commissions

On the following pages, we show bridge and culvert designs used by several of the State Highway Commissions. These designs are standard for the different states and indicate the best engineering practice in this line.

The variation in thickness of slab and amount of reinforcement in the different designs is due to different assumptions as to loading and the strength of concrete in compression. The variation in the designs indicates the variations in traffic conditions in the different states and that the State Engineers have designed the bridges to accommodate local traffic.

The larger arch bridges which are shown are all of the reinforced type. Where the cost of materials is high, this type of arch design is probably more economical than a plain concrete arch but should never be undertaken except by an experienced man. For this reason no reinforced concrete arch designs are shown.

On the other hand, the plain concrete arch is very simple of construction after the forms have been placed in position, and a man with but little experience in this class of concrete work can undertake the construction.

Figure 31 Small bridge over Dixie Run, near Hooversville, Pa.

Illinois

Figure 32 shows the standard design of the Illinois Highway Commission, A. N. Johnson, State Highway Engineer, for a flat slab bridge of 20-foot span. The following table gives quantity and size of steel reinforcement required. Because of the low clearance or head room which is obtained over the streams in Illinois, the Highway Commission has adopted the flat slab and through girder types of concrete bridges entirely.

Letter	No.	Size	Length
A	....	1 ″	25′ 0″
B	20	½″	....
C	6	½″	21′ 8″
D	40	½″	4′ 8″

Note:—

Exposed edges of girders and rails to be beveled with ¾-inch triangular molding.

Where grooved panels are shown the same to be made by ¾-inch triangular molding.

Macadam wearing surface not to be included in contract.

Concrete to be proportioned 1:2½:4.

All steel reinforcing bars must be mild or medium steel rolled from billets.

No rerolled material or high carbon steel will be permitted.

All bars must be obtained in the full lengths indicated in bill of material.

Kansas

Figure 33 is a design for a 15-foot span, flat slab bridge issued by the Office of State Engineer, Manhattan, Kansas, W. S. Gearhart, State Engineer. Amount and size of steel reinforcement required is given in the following table.

Bill of Material

Letter	No.	Size	Length
A	16	¾″ sq.	16′ 9″
A1	16	¾″ sq.	17′ 6″
A2	15	¾″ sq.	17′ 6″
B	15	½″ sq.	26′ 0″
C	6	½″ sq.	16′ 9″
D	24	¾″ sq.	5′ 0″

Concrete to be used in floor and girders, proportioned 1:2:4. Concrete to be used in wing walls and abutments proportioned 1:3:5. A ¾-inch triangular molding shall be used to bevel all exposed corners of the girders, guard rails and wing walls.

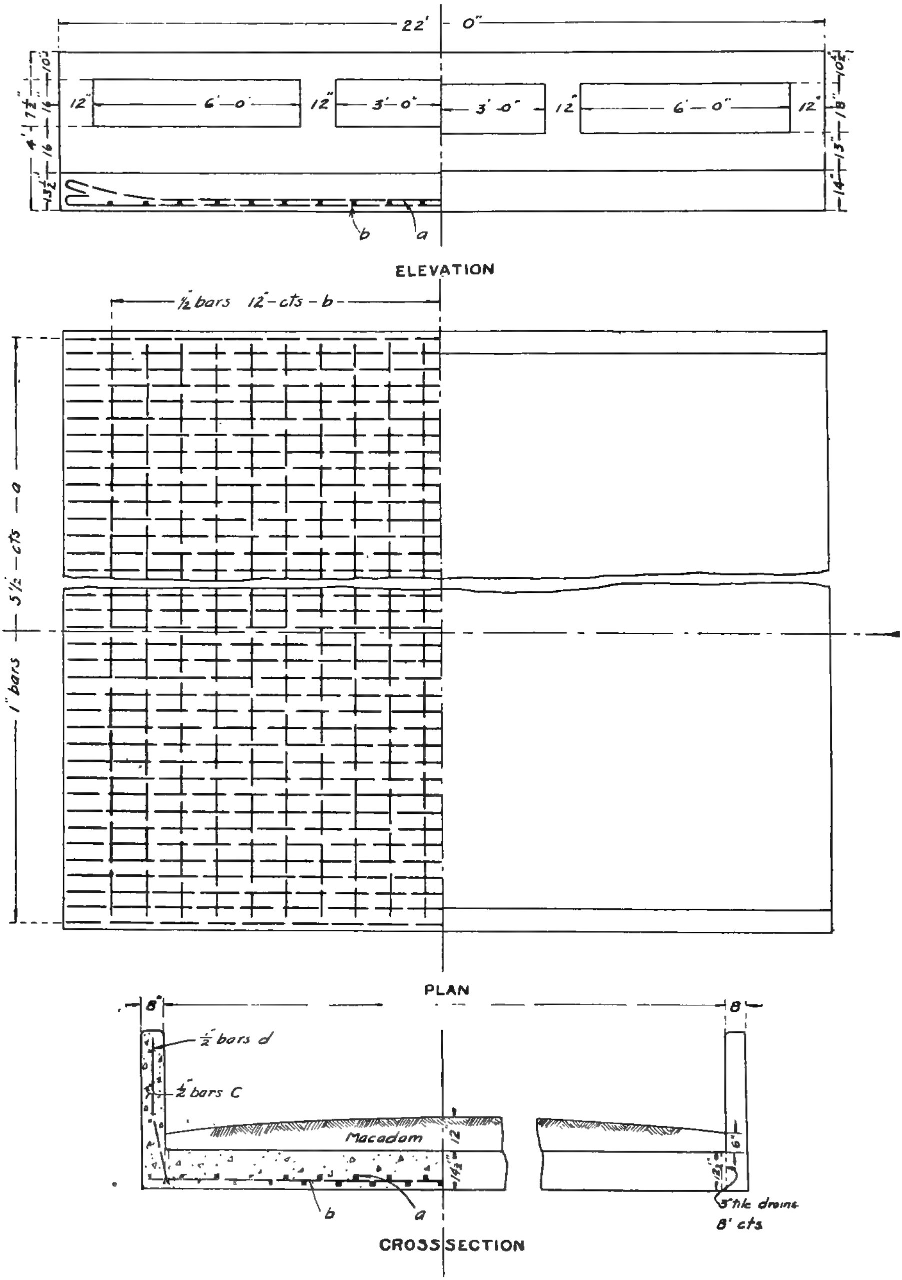

Figure 32. Concrete Superstructure of 20-foot span, 12 to 20-foot roadway. Designed by the Illinois Highway Commission.

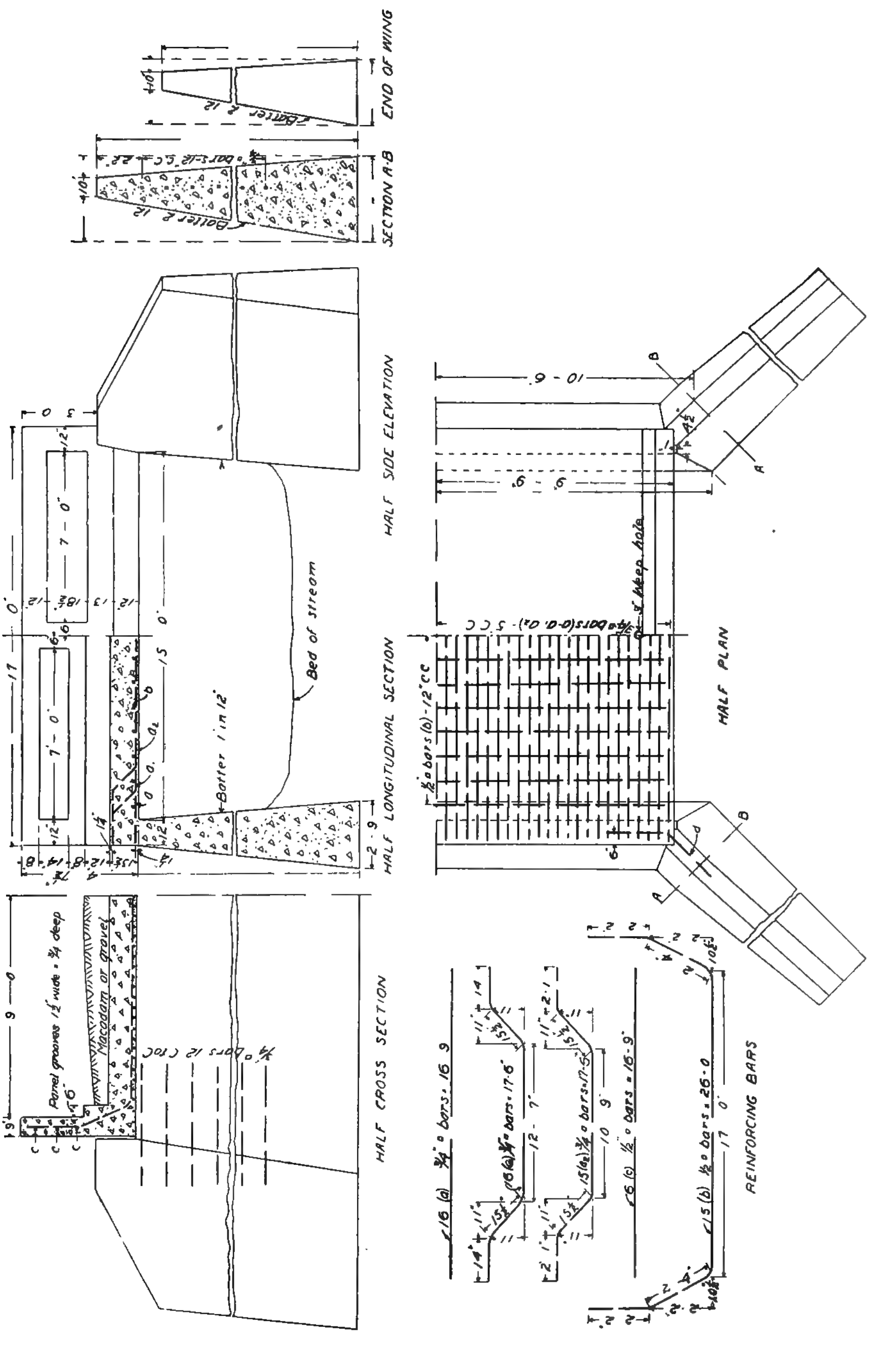

Figure 33. Concrete bridge of 15-foot span at Manhattan, Kans. Designed in the office of the State Engineer at the Kansas State Agriculture College.

New York

Figure 34 is the standard design of the State of New York, Department of Highways, for flat slab bridges 10 feet to 20 feet in span. John A. Bensel, State Engineer. The table on the following page gives slab thickness and amount of reinforcement required for the various spans.

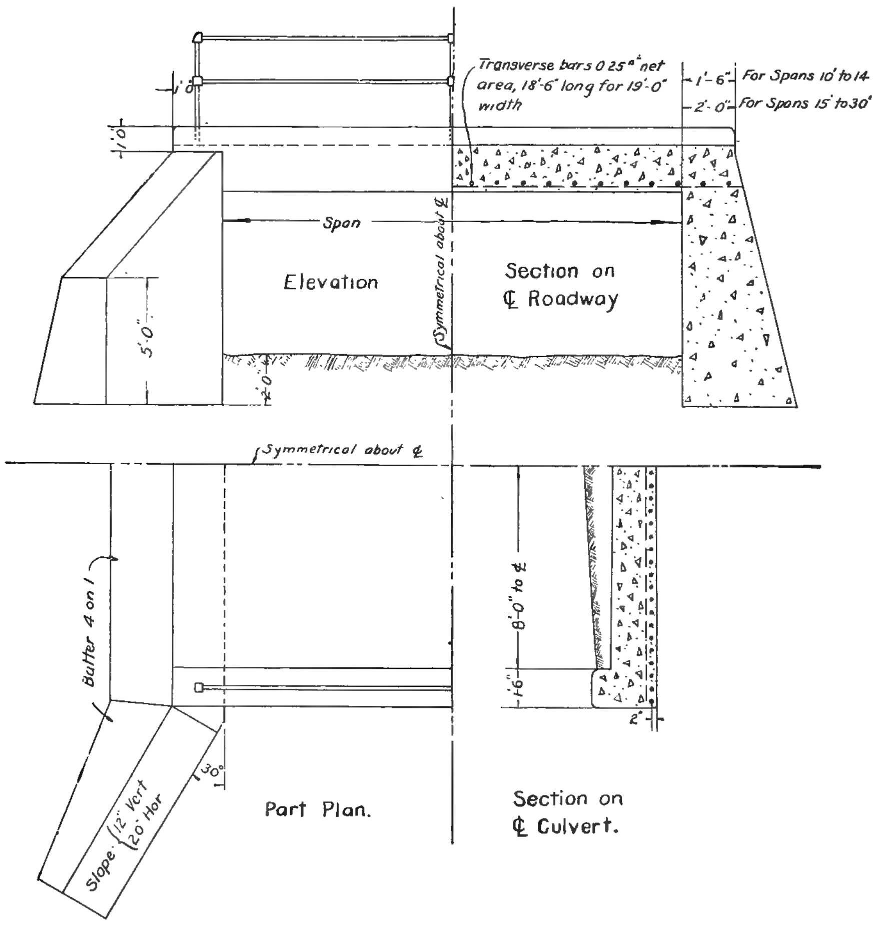

Figure 34. Standard culvert with rod reinforcement of 10 and 20-foot span. Designed by the Department of Highways of the State of New York.

Clear Span	Thickness of Slab	Cross Section of Bars	Weight per Foot of Bars	Length of Each Bar	Distance to Center of Bars
10′	12″	.56″	1.91 lbs.	13′ 0″	6½″
11′	12″	.56″	1.91 lbs.	14′ 0″	6½″
12′	13″	.56″	1.91 lbs.	13′ 0″	6 ″
13′	13″	.56″	1.91 lbs.	16′ 0″	5½″
14′	14″	.56″	1.91 lbs.	17′ 0″	5½″
15′	14″	.56″	1.91 lbs.	19′ 0″	5 ″
16′	15″	.56″	1.91 lbs.	20′ 0″	4½″
17′	15″	.56″	1.91 lbs.	21′ 0″	4½″
18′	16″	.56″	1.91 lbs.	22′ 0″	4½″
19′	17″	.56″	1.91 lbs.	23′ 0″	4 ″
20′	18″	.77″	2.60 lbs.	24′ 0″	5 ″

All rods to have a deformed cross-section.
Round all exposed edges to a 1½-inch radius.
2nd class concrete in slab.
3rd class concrete in wing walls and abutments.

Massachusetts

Figure 35 shows standard design for reinforced concrete box culverts used by the Massachusetts Highway Commission, A. W. Dean, Chief Engineer. This figure shows the designs for box culverts 1½ feet by 1½ feet; 2 feet by 3 feet; 3 feet by 4 feet and 4 feet by 5 feet. The amount of concrete and reinforcement required is given in each case.

Ohio

The design shown in Figure 36 is a Standard Concrete Bridge des gn of 9-foot span, 20-foot roadway, used by the Ohio State Highway Department. James R. Marker, State Highway Commissioner, Clyde T. Morris, Bridge Engineer. The following table gives the estimated quantities of steel and concrete for the superstructure.

All concrete work shall conform to the "General Specifications for concrete and reinforced concrete structures" of the State Highway Department.

Estimated Quantities for Superstructures

Concrete 1:2:4	13 1/10 cu. yds.
Steel—	
44 pieces ¾″ sq. t w. 11′ 6″ long	975 lbs.
9 pieces ⅜″ sq. t w. 21′ 6″ long	95 lbs.
Total Steel	1070 lbs.
Wire Netting, No. 9, 4″ to 6″ mesh	240 sq. ft.

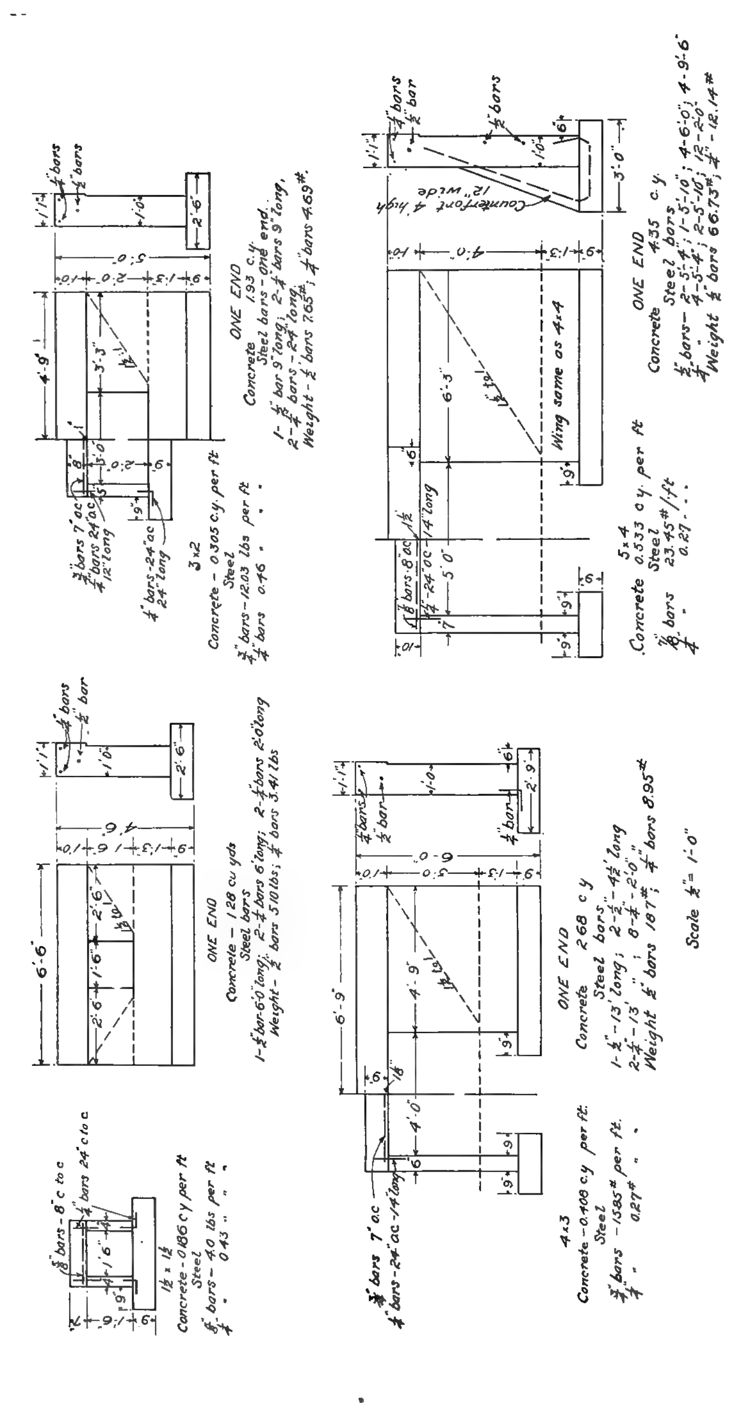

Figure 35. Standard Box Culvert Designs. Massachusetts Highway Commission.

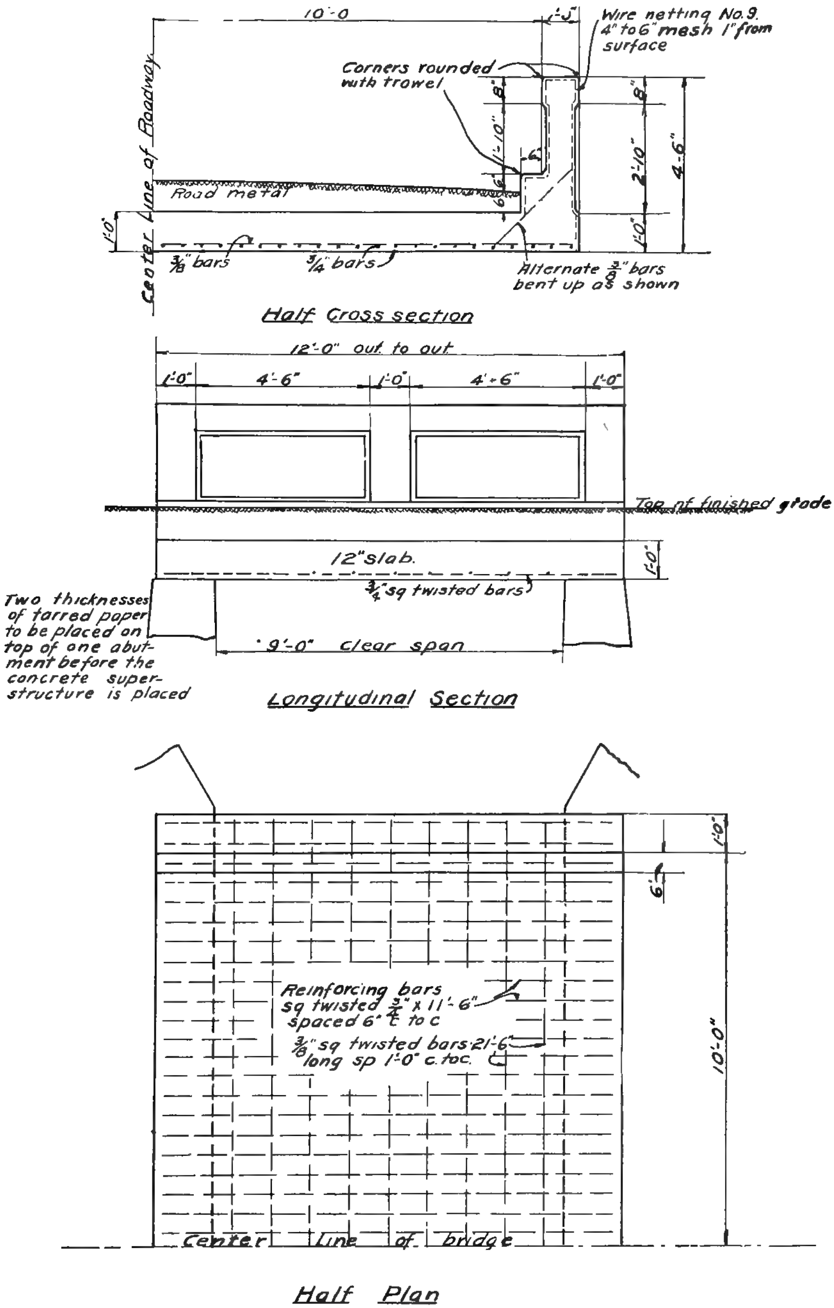

Figure 36. Standard concrete bridge of 9-foot span and 20-foot roadway. Designed by the Ohio State Highway Department. (Class "C" loading.)

Virginia

Figure 37 is the typical design for reinforced concrete slabs for highway culverts used by the Virginia State Highway Commission, P. St. J. Wilson, Highway Commissioner. Table showing amount of concrete and steel reinforcement for the various spans is given on the following page.

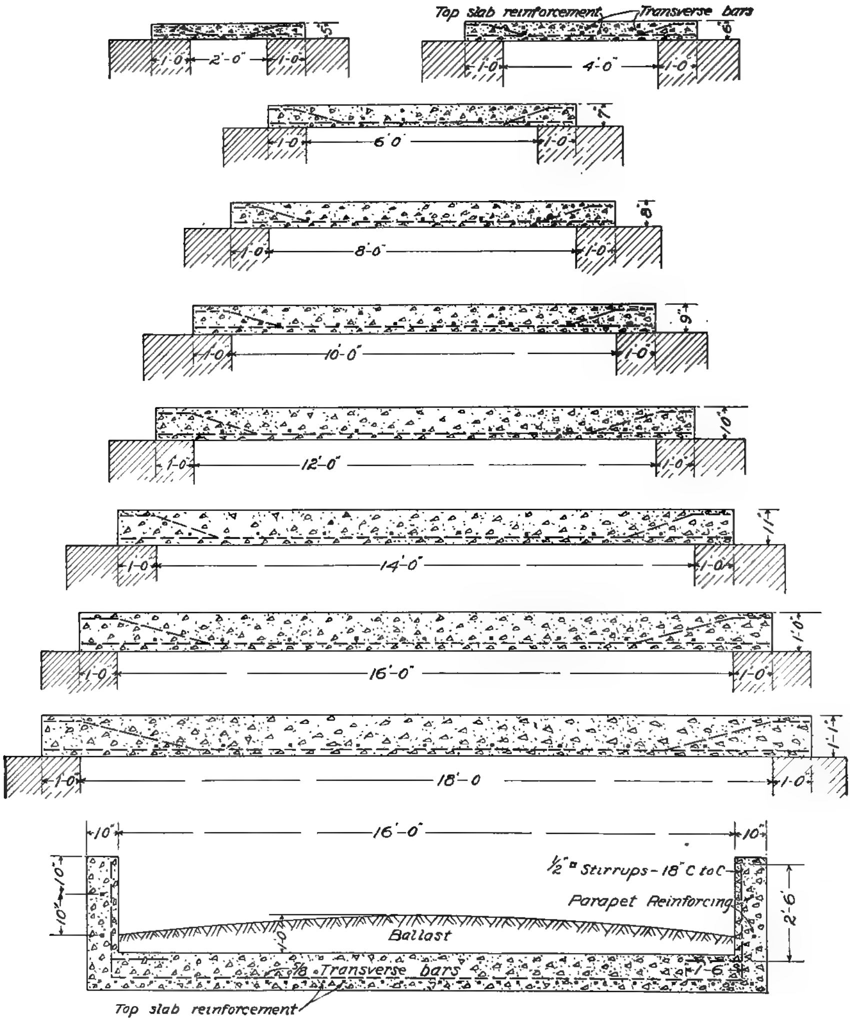

Figure 37. Typical Reinforced Concrete Slabs for Highway Culverts, Office of State Highway Commission, Richmond, Va.

Table Showing Reinforcement of the Virginia State Highway Commission's Standard Culvert Slabs

Span	Top Slab Reinforcement				Transverse Reinforcement			Parapet Reinforcement				Stirrups				Quantities	
	Size	Space	Length	No.	Size	Length	No.	Size	Space	Length	No.	Size	Space	Length	No.	Concrete Cu. Yds.	Steel Lbs.
2	5/8″	8″	4′-6″	26	5/8″	21′-3″	2	1/2″	10″	9′-6″	4	1/2″	18″	4′-0″	6	1.70	247.5
4	3/4″	8″	6′-6″	26	5/8″	21′-3″	3	1/2″	10″	[illegible]′-6″	4	1/2″	18″	4′-0″	8	2.88	456.8
6	3/4″	6″	8′-6″	35	5/8″	21′-3″	4	1/2″	10″	8′-6″	4	1/2″	18″	4′-0″	10	4.26	744.0
8	7/8″	7″	10′-6″	30	5/8″	21′-3″	5	1/2″	10″	10′-6″	4	1/2″	18″	4′-0″	12	5.99	1036.6
10	7/8″	6″	12′-6″	35	5/8″	21′-3″	6	1/2″	10″	12′-6″	4	1/2″	18″	4′-0″	16	7.73	1403.7
12	7/8″	6″	14′-6″	35	5/8″	21′-3″	7	1/2″	10″	14′-6″	4	1/2″	18″	4′-0″	18	9.75	1627.5
14	1 ″	7″	16′-6″	30	5/8″	21′-3″	8	1/2″	10″	16′-6″	4	1/2″	18″	4′-0″	20	11.99	2032.9
16	1 ″	6″	18′-6″	35	5/8″	21′-3″	9	1/2″	10″	18′-6″	4	1/2″	18″	4′-0″	24	14.51	2600.0
18	1 ″	6″	20′-6″	35	5/8″	21′-3″	10	1/2″	10″	20′-6″	4	1/2″	18″	4′-0″	26	17.25	2889.8
20	1 1/8″	6″	22′-6″	35	5/8″	21′-3″	11	1/2″	10″	22′-6″	4	1/2″	18″	4′-0″	30	20.22	3875.2

Note—Twenty feet clear span not shown. Thickness of slab 14 inches. Sizes and Sections for square bars shown in table.

All concrete 1 part No. 1 Portland cement, 2 parts sharp, clean sand and 4 parts of broken stone, sizes 1/4″ to 1 inch. Reinforcement of structural steel square bars of sizes shown. Every alternate bar bent up as shown. All bars except Stirrups and Transverse bars to be bent 3-inch at each end in addition to bending of alternate bars. All Transverse Bars to be bent up 2 feet 5 inches at each end and into Parapet as shown. Specifications Virginia State Highway Commission, 1909. Capacity: 12-Ton Roller.

Wisconsin

Figure 39 shows the standard design used by the Wisconsin Highway Commission. A. R. Hirst, Acting State Engineer; M. W. Torkelson, Bridge Engineer. The amount of steel reinforcement required is shown in figure 40.

Concrete—

Superstructure—1:2:4 mixture requires 17.3 cubic yards.
Substructure—1:3:6 mixture requires 34.0 cubic yards.
For each vertical foot of change in height of substructure, add or subtract 3.1 cubic yards.

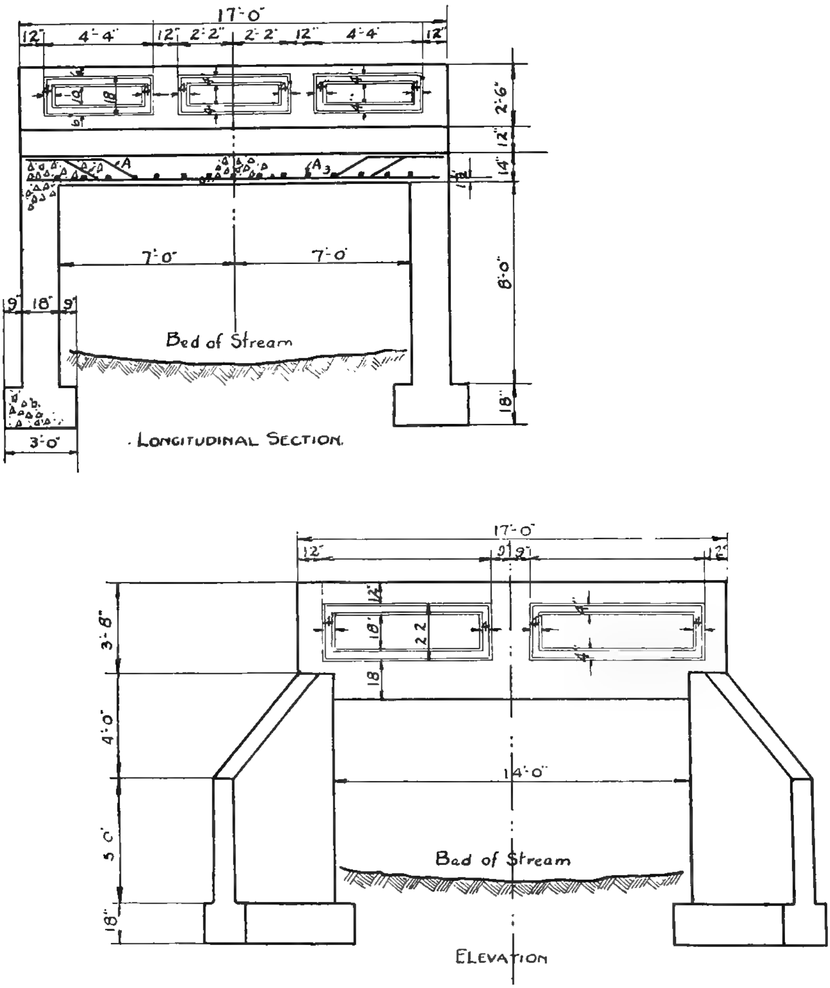

Figure 38. Section and elevation of bridge shown in Figure 40.

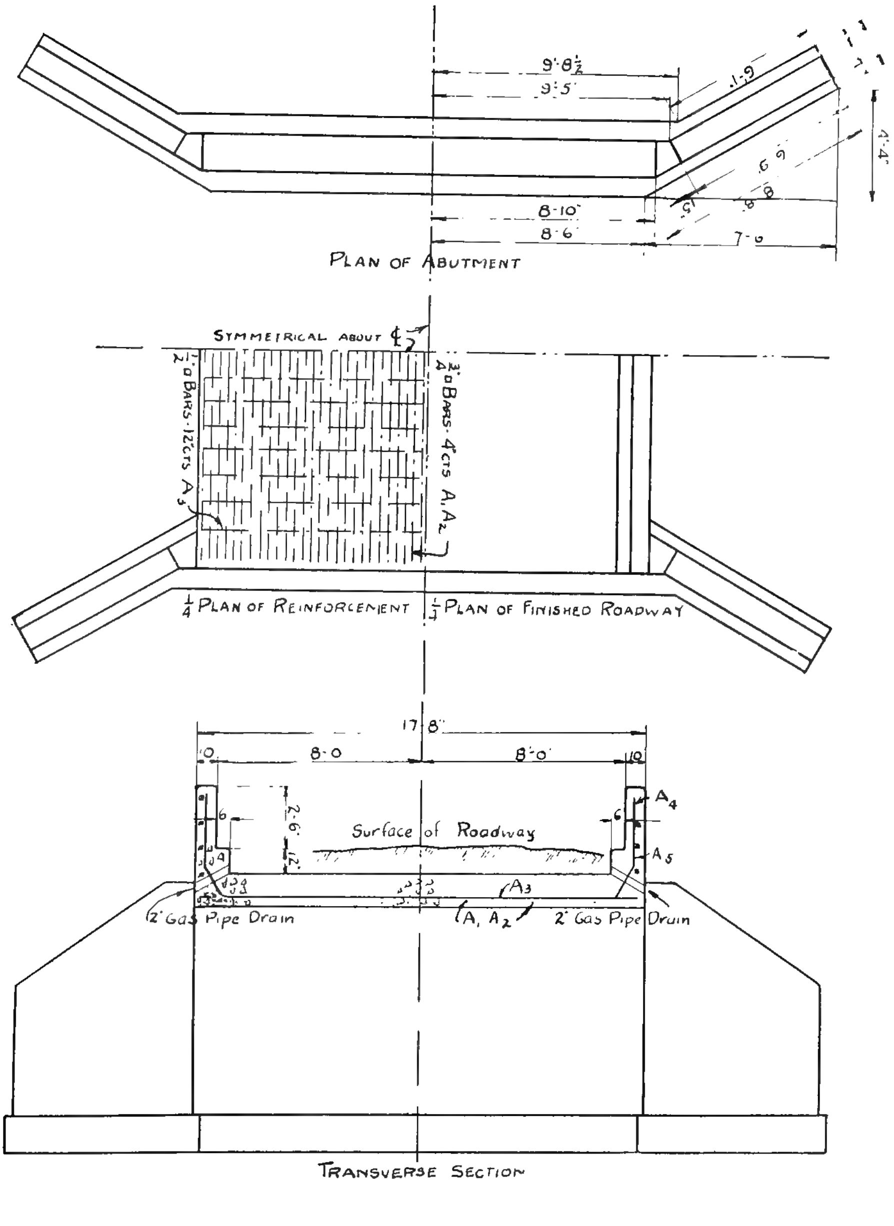

Figure 39. Concrete Bridge of 14-foot span and 16-foot roadway. Designed by the Wisconsin State Highway Commission.

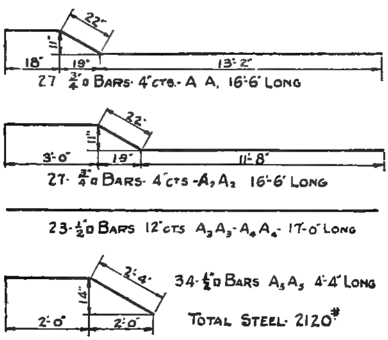

Figure 40. Bill of Material for Steel for Bridge shown in Figure 40.

Illinois

Figure 41 shows the design for plain concrete abutments used by the Illinois Highway Commission. This type of substructure is used where the height of abutment is not great or where plain concrete is desirable because of the cheapness of materials. It will be noted that the dimensions of the wing walls have been omitted in this design. This is for

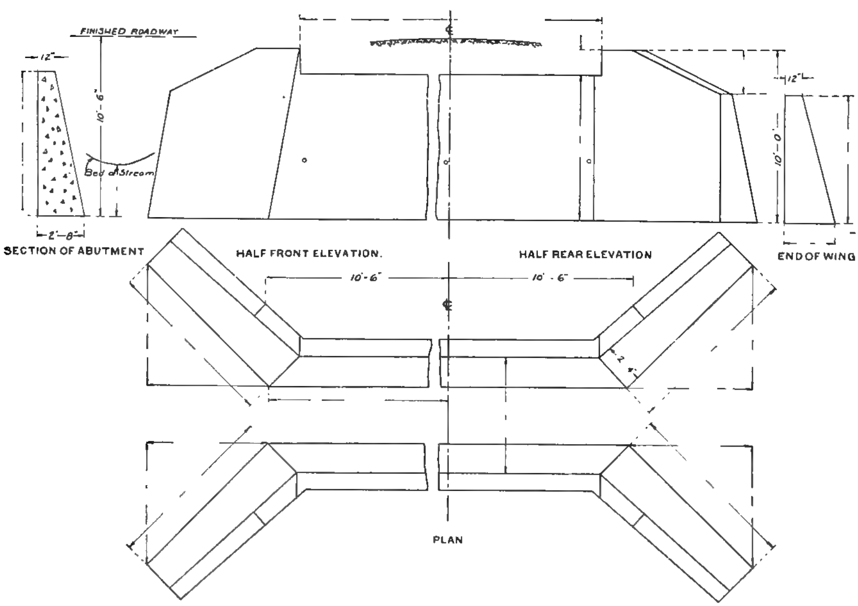

Figure 41. Concrete sub-structure of over all height of 10½ feet. Designed by the Illinois State Highway Commission.

the reason that the height and length of the wing walls is so influenced by the character of the banks of the stream that these dimensions will vary for each structure.

Note—

Use two thicknesses of building paper between adjacent surfaces of substructure and superstructure.

All exposed edges of wings to be beveled with ¾-inch triangular molding.

Concrete to be proportioned 1:3:5.

Place 3-inch tile drains in abutment walls 1 foot above ground line at abutment.

Iowa (*Arch*)

Figure 43 gives the standard design for 20-ft. span, 8-ft. rise, reinforced concrete arch culvert used by the Iowa Highway Commission, T. H. McDonald, State Highway Engineer. The wing walls in this design are shown parallel to the axis of the roadway and are reinforced. This arch is not semi-circular as it is only given an 8-ft. rise in 20-ft. span.

Design may be used with or without pavement, apron wall to be constructed in either case. Transverse arch bars to be fastened with 1½ × ¼ in. lattice bars as shown.

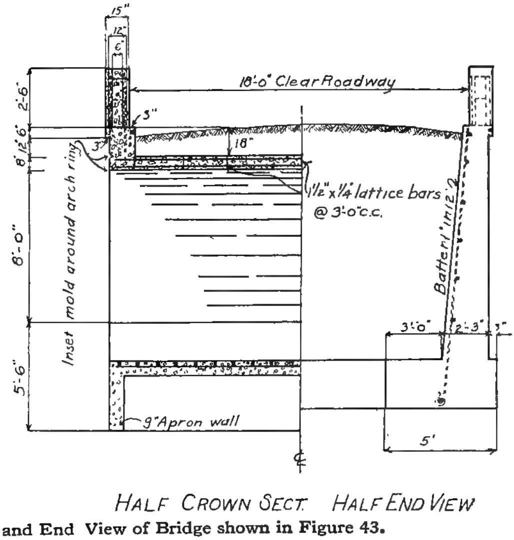

Figure 42. Section and End View of Bridge shown in Figure 43.

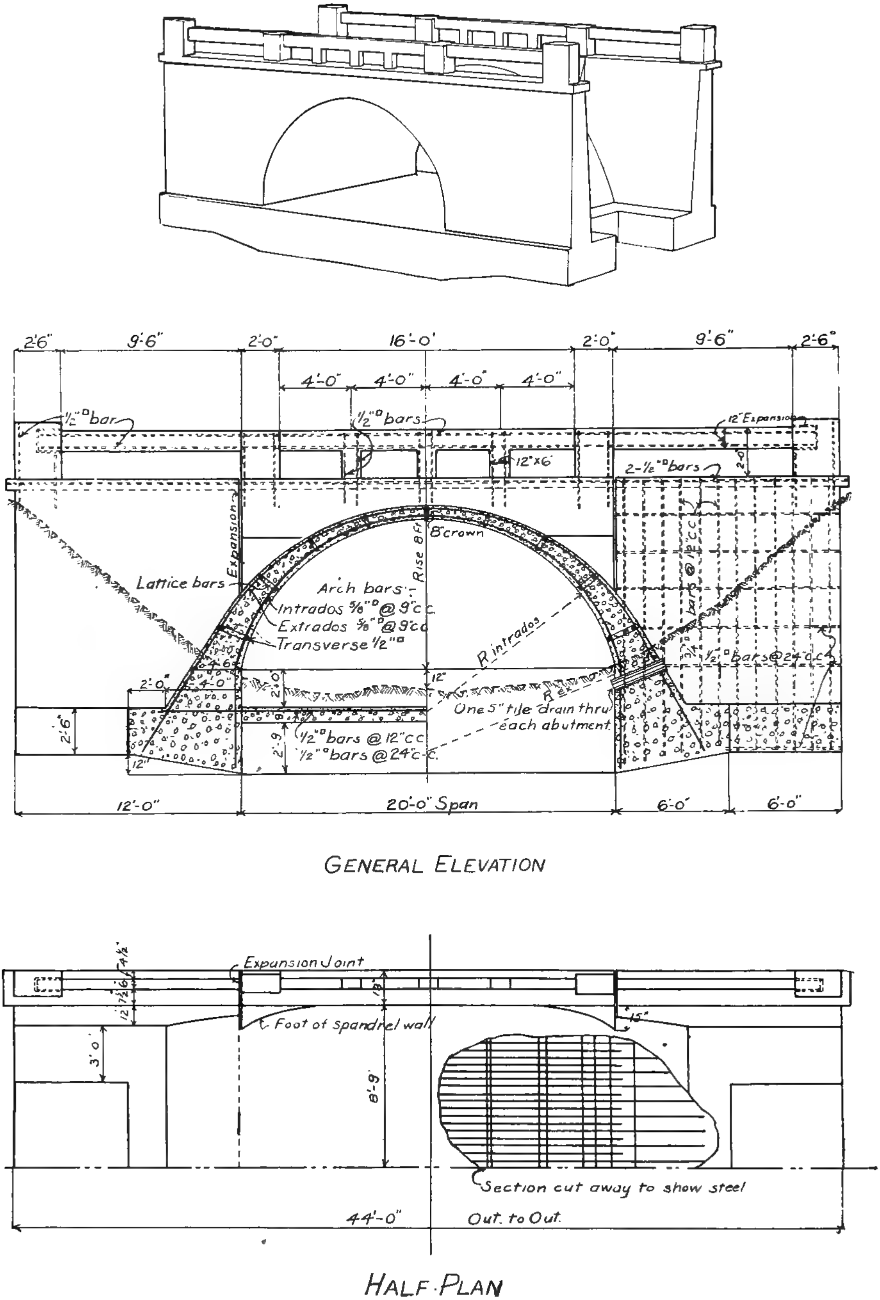

Figure 43. Standard Design. 20-foot span; 8-foot rise; Reinforced Concrete. Iowa Highway Commission.

Minnesota (Arch)

Figure 44 is the standard design for plain concrete arch culverts used by the Minnesota State Highway Commission, George W. Cooley, State Engineer. The following table gives the dimensions for the various spans.

Table of Dimensions for Plain Concrete Culverts Concrete

Sizes 2 x 2 Feet, to 4 x 4 Feet

W	H	A	B	C	D	E	F	I	K	M	N	T
2′ 0″	2′ 0″	1′ 0″	0′ 8½″	1′ 2″	5′ 5″	3′ 0″	1′ 2″	0′ 6″	0′ 6″	0′ 8″	0′ 8″	0′ 8″
2′ 0″	2′ 6″	1′ 0″	0′ 8½″	1′ 2″	5′ 3″	3′ 6″	1′ 4″	0′ 6″	0′ 7″	0′ 8″	0′ 8″	0′ 8″
2′ 6″	2′ 6″	1′ 2″	0′ 9½″	1′ 3″	6′ 5″	3′ 6″	1′ 5″	0′ 6″	0′ 7″	0′ 8″	0′ 8″	0′ 9″
2′ 6″	3′ 0″	1′ 2″	0′ 9½″	1′ 3″	6′ 5″	4′ 0″	1′ 7″	0′ 6″	0′ 8″	0′ 8″	1′ 0″	0′ 9″
3′ 0″	3′ 0″	1′ 4″	0′ 10½″	1′ 4″	7′ 5″	4′ 0″	1′ 8″	0′ 7″	0′ 8″	1′ 2″	1′ 0″	0′ 10″
3′ 0″	3′ 6″	1′ 4″	0′ 10½″	1′ 4″	7′ 5″	4′ 6″	1′ 10″	0′ 7″	0′ 9″	1′ 2″	1′ 0″	0′ 10″
3′ 6″	3′ 6″	1′ 6″	0′ 11½″	1′ 5″	8′ 5″	4′ 6″	1′ 11″	0′ 7″	0′ 9″	1′ 2″	1′ 4″	0′ 11″
3′ 6″	4′ 0″	1′ 6″	0′ 11½″	1′ 5″	8′ 5″	5′ 0″	2′ 1″	0′ 7″	0′ 10″	1′ 2″	1′ 2″	0′ 11″
4′ 0″	4′ 0″	1′ 8″	1′ 0½″	1′ 6″	9′ 5″	5′ 0″	2′ 2″	0′ 8″	0′ 10″	1′ 2″	1′ 8″	1′ 0″

Note—

Dimensions indicated by figure are constant for all sizes. Length will vary with width of roadway and depth of fill. Where ground is soft, the gutter at the outlet should be paved

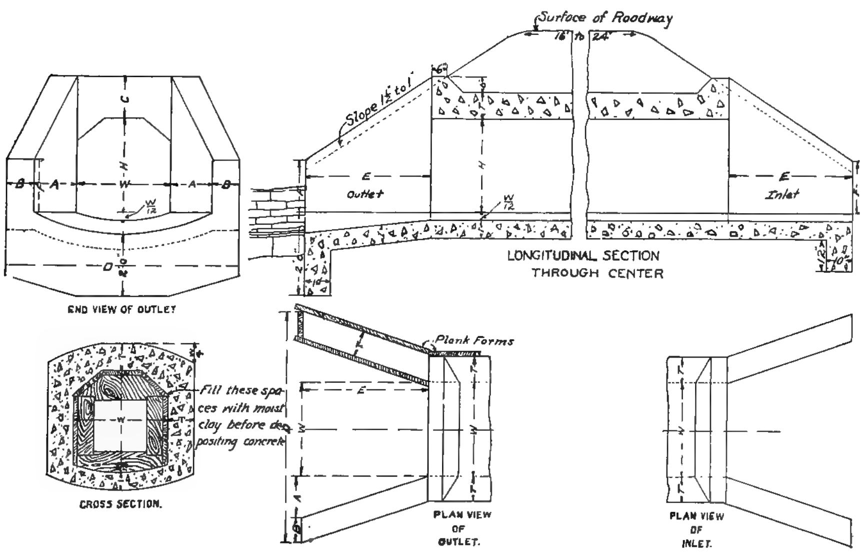

Figure 44. Concrete Culverts designed by the Minnesota State Highway Commission.

with concrete or well-shaped cobble or other suitable stone as indicated on longitudinal section.

Concrete

Concrete shall consist of one part by volume of Portland Cement, 2½ parts of clean, sharp sand and 5 parts of 2-inch broken stone or screened gravel containing pebbles from ¼-inch to 2-inch in size, or may be of 1 part by volume of Portland Cement and 5½ parts of selected pit gravel approved by County Superintendent of Highways.

U. S. Department of Public Roads (Arch)

Figure 45 shows the standard design for a Plain Concrete Arch Culvert, Span 6 foot, issued by the Office of Public Roads, U.S. Department of Agriculture Bulletin No. 39. It should be noted that this culvert is designed for a 24-foot roadway. This is the standard width used in all designs of the Office of Public Roads. The wing walls on the up-stream end of the culvert are placed at an angle of 30° to the direction of the stream flow, while those on the down stream face are placed at right angles to the roadway.

The following amount of materials will be required for this culvert.

Quantities Required

Concrete, arch and parapets (1:2:4) 12.9 cu. yds.
Concrete, side, end and wing walls (1:2½:5) 39.8 cu. yds.
Concrete, footings (1:3:6) 20.1 cu. yds.

Total Quantities

102 barrels cement.
33 cu. yds. Sand.
66 cu. yds. Stone or Gravel.

Oklahoma (Arch)

Figure 46 is the standard design of the Oklahoma State Highway Department, W. R. Goit, Engineer, for a reinforced concrete arch culvert of 15-foot span. This design shows a rise of six feet from the springing line to the crown. The use of reinforcing steel in a concrete arch permits the use of a much flatter arch than can be designed of plain concrete, and does not require as much head room as the semi-circular arch.

The following table gives amount of concrete and reinforcing steel required for this design.

Quantities of Materials for 16-foot Roadway:
Concrete, 38 cubic yards.
Steel, 1709 lbs. ½-inch square bars twisted.
For each additional 2 feet in width:
Concrete, 2 cu. yds. + 6 cu. ft.
Steel, 126 lbs.

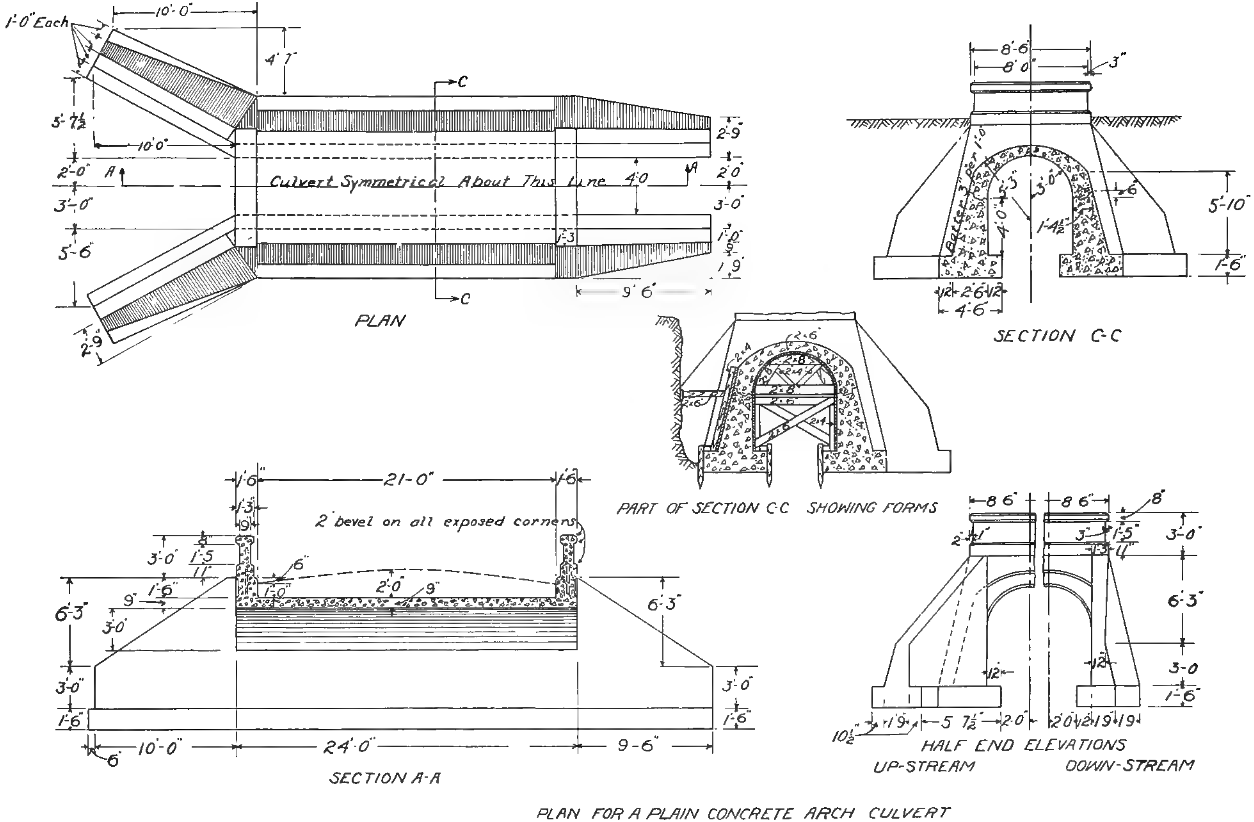

Figure 45. Plan for a Plain Concrete Arch Culvert. Span 6 feet. Office of Public Roads. U. S. Department of Agriculture.

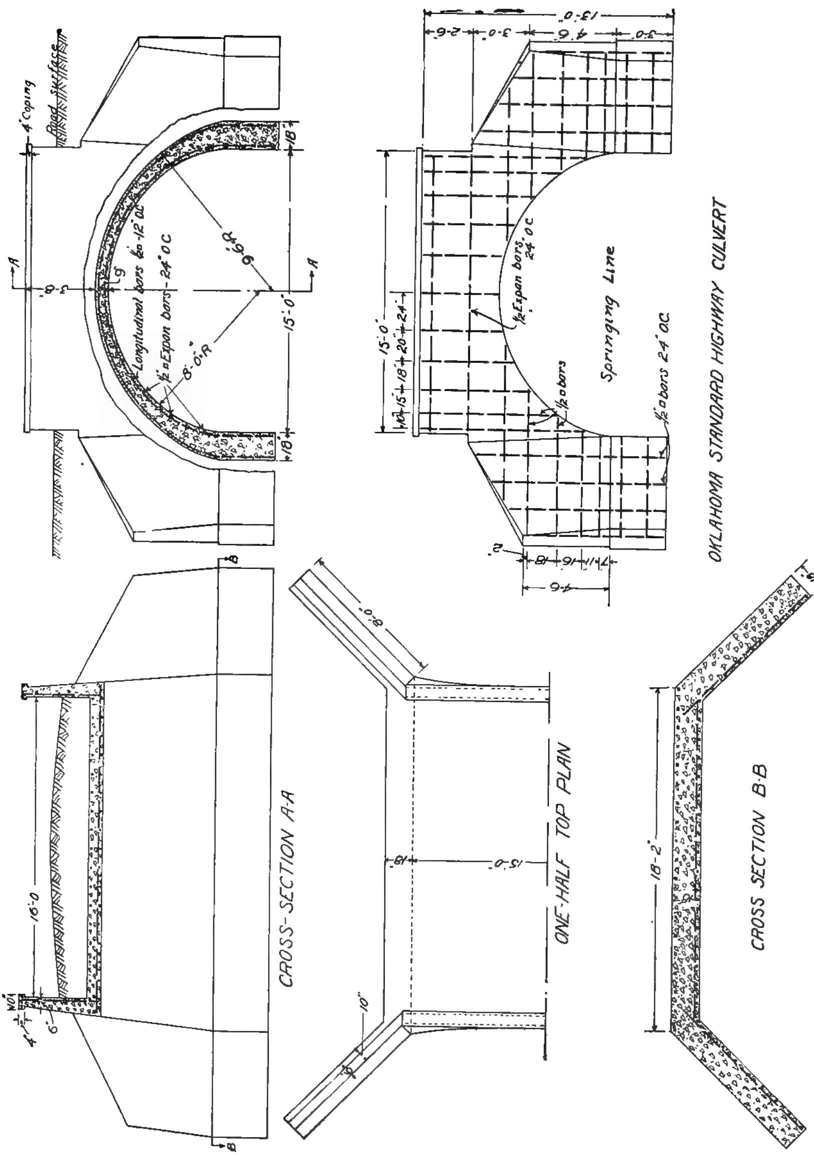

Figure 46. Standard Highway Culvert, Reinforced Concrete 15-foot Arch. Oklahoma State Highway.

Commercial Culvert Forms

There are a number of collapsible steel forms on the market for the construction of both plain and reinforced concrete culverts which are proving satisfactory. The use of a steel form for the construction of one or two small culverts is not an economical proposition, but where the country or township has a number of small culverts to build, they would probably find it advisable to invest in a set of steel forms. In the following paragraphs we give a brief description of several of the leading commercial culvert forms.

Blaw Steel Centering Co.

The Blaw Steel Construction Co., Westinghouse Building, Pittsburgh, Pa., manufactures an adjustable steel form for semi-circular arch culverts having a radius from 9 in. to 24 in. and a height of side wall of 1 ft. 3 in. This form comes in lengths from 6 ft. to 16 ft. and is easily adjustable to all the intermediate sizes. They also have forms for box culverts. These forms come in five foot sections which are made in three sizes, being capable of a large range of adjustment. No. 1 adjusts from 24 in. by 24 in. to 32 in. by 32 in.; No. 2 from 30 in. by 30 in. to 38 in. by 38 in; and No. 3 from 36 in. by 36 in. to 44 in. by 44 in. This company also manufactures steel lagging which can be used in the construction of large box culverts, retaining walls, etc., and collapsible arch ribs which are used with wooden lagging on arches 20 ft. and larger in span.

Figure 47. Luten type reinforced concrete bridge near Holliday's Cove, West Virginia, which withstood unusual flood conditions, the only damage being to the concrete railing which was shattered by the debris carried by the flood.

Concrete Form and Engine Co.

The Concrete Form and Engine Co. of Detroit, Michigan, manufactures a collapsible steel form which is not adjustable. It comes in sections 10 feet long and in 10 sizes, having a semi-circular top ranging 6 in. to 37 in. in radius, while the height of the sides ranges from 9 in. to 42 inches. The tops and sides are all interchangeable which permits some range of adjustment. Two sections make a complete form and consist of the semi-circular tops, sides and end plates.

The side plates are held in position by swinging braces, so that when locked the sides are immovable. The top, setting between the two side plates, is held in position by arms attached to the side plates by bolts which allow the arms to be lowered by pulling the draw rods attached to them. End plates are made which fasten to the top and side plates by keys so that they may be removed easily.

The forms are made of 16-gauge galvanized steel covering, reinforced by steel ribs on the inside and the working parts are comparatively simple and easy to operate.

Dooley Steel Center Co.

The Dooley Steel Center Co. of Fond du Lac, Wisconsin, manufactures a form consisting of a one-piece circular shell with turnbuckle ribs and a wire gauge ring. It is manufactured in 15 sizes from 18 in. in diameter to 72 in. in diameter, five of the larger sizes being adjustable to a slight extent. The forms are made in 10-foot sections which can be telescoped one within the other, giving forms of any length. This form is not provided with end or side plates but has the advantage of being extremely simple in construction. To use this form, it is necessary first to fill the bottom of the proposed culvert trench with concrete. The form is then set on this fresh concrete and the concrete for the top and sides deposited around the form.

Figure 48. Concrete Culvert, McLean County, Illinois. 42-inch diameter; 20 feet in length. Built by Township Commissioners in 10 hours over Merrillat culvert forms. Cost, exclusive of form, $62.50.

The Kelly Manufacturing Co., of Waterloo, Iowa, manufactures a collapsible steel form for culverts 13 in. to 48 in. in diameter and 16, 18, 20 and 24 feet in length. It is a circular culvert form similar to the one described above, but is provided with end plates for the construction of the end walls. It is necessary to deposit concrete first in the bottom of the trench and then set the form on this fresh concrete. The form is easily collapsed by drawing the tie rod and all the working parts are of very simple construction. This mold is manufactured by the above company but is placed on the market through their selling agents, the Waterloo Cement Machinery Corporation, Waterloo, Iowa.

Kelly Mfg. Co.

The Merrillat Culvert Core Co., of Winfield, Iowa, manufactures a collapsible steel form adjustable to any size from 20 in. to 48 in. in diameter. This form consists of a circular core adjusted by ribs radiating from a steel center shaft, and controlled by a hand wheel at one end. The cores are made in 8 and 10 foot lengths and are used in sets of two. With this form, the concrete must first be placed in the bottom of the trench and the form then placed upon it, after which the concrete for the sides and top of the culvert is deposited around the core.

Merrillat Culvert Core Co.

There are no end plates with this form and its great advantage lies in the fact that it is so easily adjusted to any size. The form is substantially and durably built; all the operating parts are of malleable iron and every part that comes in contact with the concrete is heavily galvanized. This form is also equipped with trucks which make it easily portable. The Merrillat Company also manufactures an adjustable arch form for arches from 6 to 12 feet in span.

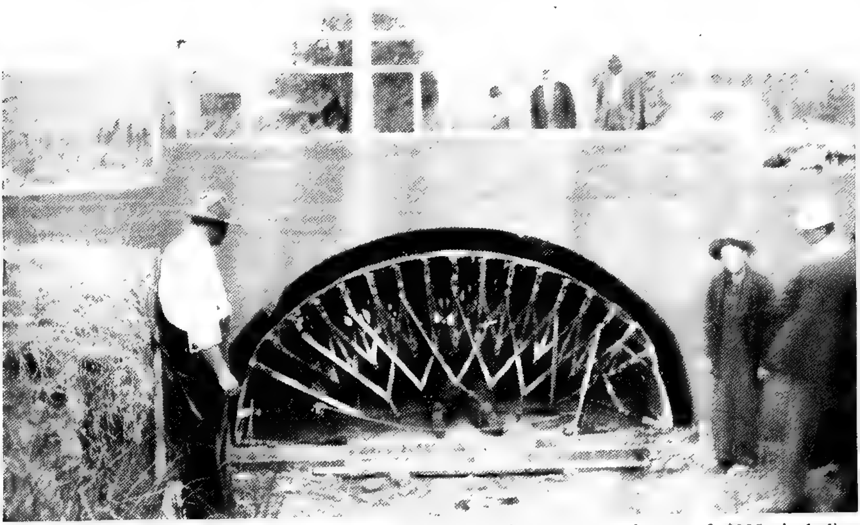

Figure 49. This bridge was built in Adams County, Nebr., at a total cost of $225, including material, labor and freight on gravel, which was shipped in by rail. The span is 12 feet, the roadway 16 feet and the wings, 7 feet long. The form used in this case is adjustable for spans from 6 to 12 feet and can be set at any angle across the road.

The Merrillat Co. also manufacture an adjustable arch form for arches ranging from 6 to 12 feet in span and in units of 4 feet in length so that bridges may be built of any length by using additional sections. This form is also adjustable at any angle across the road and may be set up in a few hours and after the concrete has set can be removed in a few minutes. The form is in the shape of a half ellipse but the curve may be adjusted to suit the user.

Township Supply Co.

The Township Supply Co., of St. Louis, Mo., manufactures an adjustable circular steel form which comes in two sizes; one can be adjusted from 14 in. to 24 in. in diameter, the other from 24 in. to 60 in. in diameter. It is adjusted from a steel shaft operating iron geared sprockets. The central shaft is operated by a worm screw at one end of the form and the adjustment to any size is quickly and easily made. These forms are furnished in sets, two 8-foot sections of 16 lineal feet to the set. The smaller size can also be furnished in 10 foot sections.

The concrete for the base of the culvert must be deposited first, the form then placed on this base and the concrete for sides and top of culvert deposited around the form. No end plates are furnished with this core. The outside of the form is 16-gauge galvanized steel and all parts are steel and malleable. This core is easily and quickly adjusted to any size within its range.

Figure 50. Concrete arch bridge on the P. C. C. & St. L. Railroad, Columbus, Ohio, built in 1909. The flood at this point was of such a character that the brick pavement underneath the bridge was entirely washed away leaving only the concrete foundations.

Specifications for Concrete Bridges

Materials

1. Cement. The cement shall meet the requirements of the Standard Specifications for Portland Cement of the American Society for Testing Materials or the United States Government Specification for Portland Cement, Circular No. 33, Bureau of Standards.

2. Fine Aggregate for Concrete. Fine aggregate shall consist of sand, crushed stone or gravel screenings, graded from fine to coarse and passing, when dry, a screen having one-quarter (¼) inch diameter holes; shall be preferably of silicious material, clean, coarse, free from dust, soft particles, loam, vegetable or other deleterious matter, and not more than three (3) per cent shall pass a sieve having one-hundred (100) meshes per linear inch. Fine aggregate shall be of such quality that mortar composed of one (1) part Portland cement and three (3) parts fine aggregate by weight, when made into briquettes will show a tensile strength at least equal to the strength of 1:3 mortar of the same consistency made with the same cement and Standard Ottawa sand. In no case shall fine aggregate containing frost or lumps of frozen material be used.

3. Coarse Aggregate for Concrete. Coarse aggregate shall consist of inert materials such as screened gravel or crushed stone graded in size, passing a 1½-inch screen and retained on a screen having one-quarter (¼) inch diameter holes; shall be clean, hard and durable, free from dust, vegetable or other deleterious matter, and shall contain no soft, flat or elongated particles. In no case shall coarse aggregate containing frost or lumps of frozen material be used.

4. Natural Mixed Aggregates. Natural mixed aggregates shall not be used as they come from the deposit but shall be screened and remixed to agree with the proportions specified.

5. Water. Water shall be clean, free from oil, acid, alkali, or vegetable matter.

6. Reinforcing Metal. The reinforcing metal shall meet the requirements of the Standard Specifications for Steel Reinforcement adopted March 16, 1910, by the American Railway Engineering Association, and shall be free from rust, scale or coatings of any character which will tend to reduce or destroy the bond.*

Construction

7. Forms. Forms shall be substantial, unyielding and so constructed that the concrete will conform to the designed dimensions and contours and shall also be tight to prevent the leakage of mortar. The supports for bridge floors and arches shall remain in place until time for removal as hereinafter specified.

Note:—Unless otherwise specified the steel referred to in this book is what is known as *Manufacturer's Standard Specification, Structural Steel Grade,* commonly known as soft steel.

8. Reinforcement. The reinforcement shall be placed and held in position so that it will not become disarranged during the depositing of the concrete. Whenever it is necessary to splice tension reinforcement, the character of the splice shall be such as will develop its full strength. Splices at the point of maximum stress shall be avoided.

Measuring and Mixing

9. Measuring. The method of measuring the materials for the concrete, including water, shall be one which will insure separate, uniform proportions at all times. A sack of Portland cement (94 lbs. net) shall be considered one (1) cubic foot.

10. Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass shall be used. The ingredients of the concrete or mortar shall be mixed to the desired consistency and the mixing shall continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous.

11. Hand Mixing. When it is necessary to mix by hand, the materials shall be mixed dry on a watertight platform until the mixture is of uniform color, the required amount of water added, and the mixing continued until the mass is uniform in color and homogeneous.

12. Retempering. Retempering, that is, remixing mortar or concrete that has partially hardened with additional water, will not be permitted.

Figure 51. Two Concrete Culverts near Rice Lake, Wisconsin. 24-inch diameter; 17-feet long. Built over forms of Concrete Form & Engine Co., at cost of $10.25 each.

Abutments

13. PROPORTIONS. The concrete for the abutments shall be mixed in the proportion of one (1) sack Portland cement, two and one-half ($2\frac{1}{2}$) cubic feet of fine aggregate, and five (5) cubic feet of coarse aggregate.

14. CONSISTENCY. The materials shall be mixed wet enough to produce a concrete of a consistency that will flow into the forms but which can be conveyed from the mixer to the forms without the separation of the coarse aggregate from the mortar.

15. PLACING. The concrete shall be placed in a manner that will permit the most thorough compacting. Where the work is interrupted so that the last layer of concrete shall have hardened before the next can be placed, concrete previously placed shall be roughened, cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one (1) sack of Portland cement and one and one-half ($1\frac{1}{2}$) cubic feet of fine aggregate. The concrete shall be placed in continuous horizontal layers and vertical joints avoided where possible.

Bridge Floors

16. PROPORTIONS. The concrete shall be mixed in the proportion of one (1) sack Portland cement, two (2) cubic feet of fine aggregate, and four (4) cubic feet of coarse aggregate.

17. CONSISTENCY. The materials shall be mixed wet enough to produce a concrete of a consistency that will flow into the forms and about

Figure 52. Concrete Culvert, Amherst, Massachusetts. Designed by Massachusetts Highway Commission. 2-foot by 2-foot Opening. 24-foot Roadway. Cost $102.

the metal reinforcement, but which can be conveyed from the mixer to the forms without the separation of the coarse aggregate from the mortar.

18. Placing. The concrete shall be placed in a manner to insure of its being thoroughly worked around the metal reinforcement and into the recesses of the forms. It shall be deposited for the full thickness of the floor and be brought to a surface at the established grade of the bridge floor.

Arches

19. Proportions. The concrete for the arch ring shall be mixed in the proportion of one (1) sack Portland cement, two (2) cubic feet of fine aggregate, and four (4) cubic feet of coarse aggregate.

20. Consistency. The materials shall be mixed wet enough to produce a concrete of a consistency that will flow into the forms but which can be conveyed from the mixer to the forms without the separation of the coarse aggregate from the mortar.

21. Placing. Where possible the concrete for the arch ring shall be deposited in a single day. Where impossible to deposit the concrete in a day, the arch ring shall be divided into transverse sections, each section taken as a day's work. The concreting shall commence either at the crown or at the springing line. In no case shall a joint be made at the crown.

Surface Finish

22. All exposed surfaces shall be finished to have a smooth and neat appearance.

Removal of Forms

23. Time of Removal. In no instance shall any form be removed within less than 48 hours. The supports for slab floors and bridge arches must remain in place at least 28 days. When freezing weather occurs, an extension of time equal to the time structure has been exposed to freezing shall be added to the above.

The bridge shall not be open to traffic and no extraneous loading shall be placed upon the concrete before the removal of the forms.

24. Temperature Below 35 Degrees F. If at any time during the progress of the work there is liability of the temperature dropping to 35 degrees Fahrenheit at night, the water and aggregate shall be heated and precautions taken to protect the work from freezing.

CONCRETE IN HIGHWAY CONSTRUCTION

A Text-Book for Highway Engineers and Supervisors

Price $1.00

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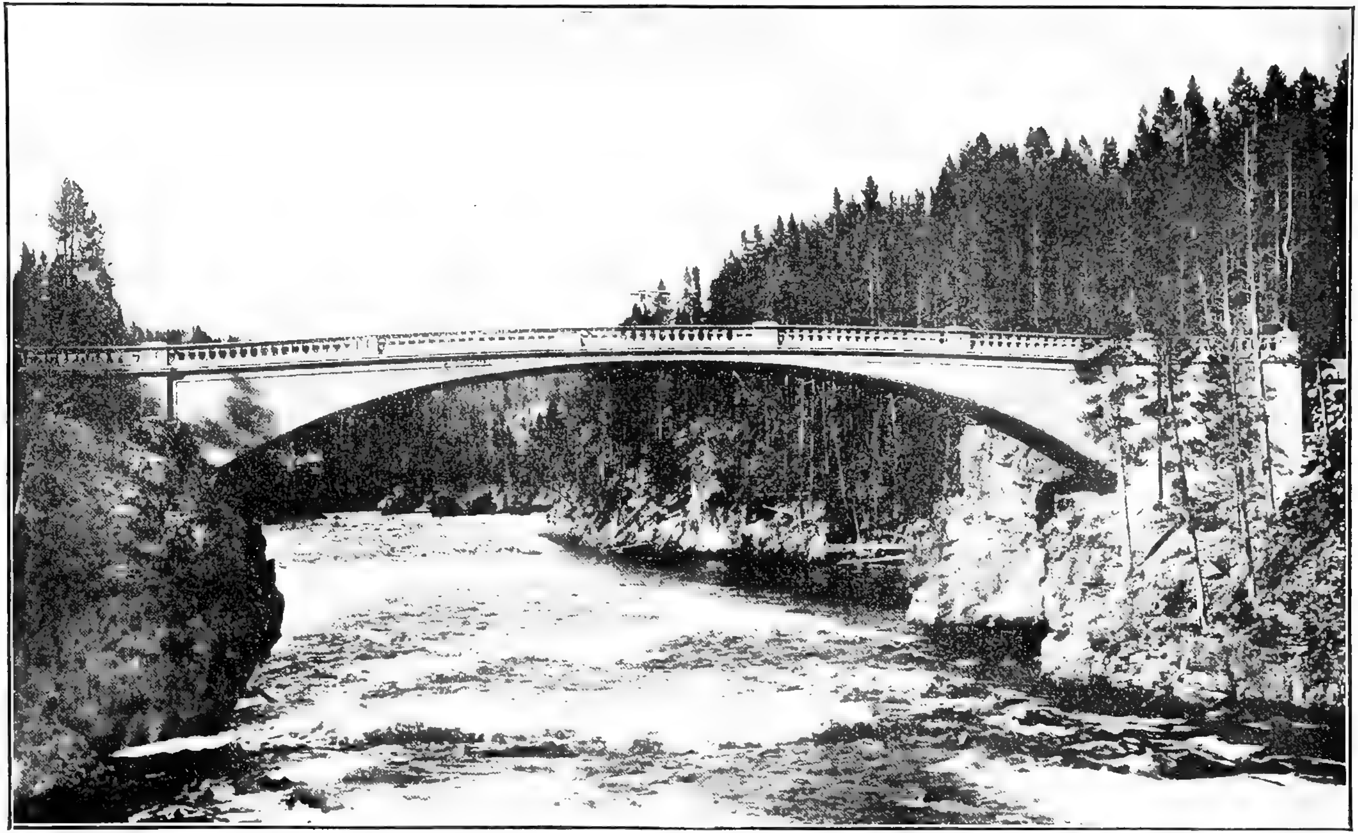

CONCRETE BRIDGE OVER THE YELLOWSTONE RIVER, YELLOWSTONE NATIONAL PARK

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CHAPTER V.—CULVERTS.

CHAPTER VI.—BEAM BRIDGES.

CHAPTER VII.—ARCH BRIDGES.

CHAPTER VII.—RETAINING WALLS.

CHAPTER IX.—MISCELLANEOUS.

FOREWORD.

The development of manufacture and of agriculture, which require proper transportation facilities not only on the railroads but to the points of shipment and distribution, has stimulated a widespread interest and called national attention to the necessity for better pavements and for highway constructions of a more permanent and durable character.

This demand, as well as the necessity for reducing the expense of repairs incident to automobile traffic, has brought to the forefront the use of concrete to produce permanent construction, not only for sidewalks and pavements, but for highway structures, such as bridges, retaining walls, culverts, and the many smaller details, the repairs to which are continually vexing the City and Town Engineer and the Highway Commissioner.

The purpose of the present volume, then, is to present to those in charge of street and highway construction and maintenance, examples of work which have been satisfactorily performed, and, further, to give drawings and designs made especially for The "ATLAS" Portland Cement Company, either as reproductions of existing structures, from drawings and photographs kindly furnished by the local authorities, or as original designs prepared by expert engineers at the request of the "ATLAS" Portland Cement Company.

The most important matter of sidewalk construction is taken up in considerable detail, while concrete street pavement construction has been thoroughly investigated, and recommendations made of methods which have produced durable and satisfactory results. Numerous examples and suggestions are given in the line of bridge design and construction, both for arches and flat bridges; sewers, culverts and retaining walls are quite thoroughly treated; and such minor structures as drains, brook linings, fences and posts, are illustrated and described.

Although the information in this little volume is more valuable and in much greater detail than is customarily presented by manufacturing companies, the position of The "ATLAS" Portland Cement Company as the leading cement manufacturers in the world has led them to present data which will tend not only toward an increasing use of cement but toward a use of cement according to the best, safest and most economical practice.

This present volume together with the other books of The "ATLAS" Portland Cement Company, namely, "Concrete Construction About the Home and on the Farm"; "Concrete Country Residences"; "Reinforced Concrete in Factory Construction," and "Concrete in Railroad Construction," covers a wide range in the use of concrete.

THE ATLAS PORTLAND CEMENT COMPANY.

New York, June, 1909.

CHAPTER I.

CONCRETE.

During the year 1907 the State Highway Commission of Massachusetts spent $468,000 in the construction of new roads and $106,000 for repairs and maintenance of roads in its charge. The State Highway Department of Pennsylvania expended $3,187,000 in the construction of new roads up to January 1, 1908, and in the report of this department for 1907 the sum of $29,225,000 is given as the total cost of roads completed, under contract and to be built. Other States are similarly engaged in building new roads, and improving old ones so that the movement for better roads and streets is almost universal. Such enormous costs of construction and maintenance show the necessity for the selection of materials which, in the long run, are the cheapest and most economical.

Concrete is playing a large part in this construction and re-construction, not so much in the roadbed proper, although as is shown in the pages which follow, concrete street pavements are well adapted to certain conditions, but especially for the various structures which are necessarily incidental to road building.

This class of work includes not only such structures as are necessary in first-class streets or highways, such as culverts, bridges and retaining walls, but also in the roadway itself, either as a foundation for a stone, brick or asphalt surface, or as a complete pavement including foundations and wearing surfaces.

For smaller uses concrete has a still wider field. For sidewalks, curbs and gutters its use is becoming quite universal, while as a material for drain tiles, lamp posts of various styles, hitching posts, fence posts, and many other highway appurtenances, its value is fast being recognized, as is shown by the enormous increase in its use for such purposes. As a material for building park structures, such as bridges, buildings, drinking fountains, and seats, concrete is well suited because of its cheapness, durability, and the ease with which it is molded into artistic designs.

In the larger structures such as bridges and retaining walls, especially where steel reinforcement is necessary to give the required strength, a proper design with good working drawings showing the dimensions and the location of the steel is of the utmost importance, and where the structure is of appre-

ciable size a competent engineer familiar with the principles of design and with practical construction in concrete should be employed to prepare plans and specifications, and to superintend the construction. On the other hand, many of the minor details can be built with but little engineering experience, provided directions given by competent authorities are carefully followed, and good judgment is used in the selection of the materials and in the work of construction.

The principal requisites of a material used in building various structures forming the necessary parts of a well-constructed, modern highway are cheapness and durability. If the first cost of the structure is to be small the materials used in its construction must be cheap and must be easily placed in position by ordinary workmen, and if the cost of maintenance is not to be excessive the materials used must possess qualities that will enable them to withstand the elements successfully. Wood, steel, stone, and concrete are in general the principal materials used in the construction of highway appurtenances such as bridges, culverts, sidewalks, curbs, and gutters. Of these four materials wood is usually the cheapest in first cost for small structures and is the least durable of all. The cost of maintenance of ordinary wooden bridges is so great and the life is so short that wood is really no longer considered seriously as a material for first-class construction, especially in those localities where lumber is scarce. Stone is generally a durable material of construction, but its first cost, and in many places its scarcity, tend to limit its use for highway purposes. It is also difficult and expensive to shape stone into desired forms which in many cases are required to secure the best results. The importance of steel in the construction of highway bridges of long spans is well understood, but its cost and the constant heavy maintenance charges, or its rapid deterioration if not properly maintained, have caused builders of bridges to seek some other material which is lower in first cost and which will not require constant painting. Clearly, concrete, or concrete with steel imbedded in it to reinforce it, is the material above all others that combines the advantages of cheapness and durability. Concrete can be made at small expense in practically any locality; can be molded in any desired shape or size; requires no maintenance, and can be placed in position with very little skilled labor.

In making concrete the cement, sand, and stone or gravel should be carefully chosen, thoroughly mixed, and properly laid. If these precautions are taken the mass will begin to stiffen in an hour or so after being laid and will continue to harden until in about one month's time the mass becomes a hard compact stone.

CEMENT.

Portland cement of first-class reputation should be used to obtain the greatest uniformity, reliability and the highest strength. If the work is small and unimportant and a brand of cement of first-class reputation is purchased from a reliable dealer no testing is necessary, but for important structures the cement should be tested and should meet the requirements of the American Society for Testing Materials.* If it is impracticable to make these complete tests, specimens may be made to see if the cement sets up properly. The following, also, is a simple test for determining the soundness of the cement:

A sound cement will not crumble when placed in the work and a test for soundness is therefore of considerable importance. Oftentimes no other test need be made. Mix, by kneading 1½ minutes, one cupful of Portland cement with enough water to form a paste having a consistency like that of ordinary putty. Place part of this paste on each of 3 pieces of glass about 4 inches square so as to make a pat about 3 inches in diameter and ½ inch thick at the center tapering down to a thin edge. Leave these 3 pats under a damp cloth arranged so that it will not touch them for 24 hours. Then place one pat in air at an ordinary temperature for 28 days, a second pat in water for 28 days, and the third pat in a tightly closed vessel over boiling water for 5 hours. If the cement is of good quality the pats will show no radial cracks and they will not crumble. If the time is limited and the pat placed in steam shows no signs of crumbling the cement may be accepted on this steam test alone.

Portland cement is manufactured from a mixture of two materials, one of them a rock like limestone or a softer material like chalk which is nearly pure lime, and another material like shale, which is a hardened clay, or else clay itself. In other words, there must be one material which is largely lime and another material which is largely clay, and these two must be mixed in very exact proportions determined by chemical tests, the proportions of the two being changed every few hours to allow for the variation in the chemical composition of the materials.

"ATLAS" Portland Cement is made by quarrying each of these materials, crushing them separately, mixing them in the exact proportions, and grinding them to a very fine powder. This powder is fed into long rotary kilns, which are iron tubes about 5 or 6 feet in diameter lined with fire brick and over 100 feet long. Powdered coal is also fed into the kilns and burned at a temperature of about 3,000 deg. Fahr., a temperature higher than that needed to melt iron to a liquid and there is formed what is called cement clinker, a kind of dark porous stone which looks almost exactly like lava.

*These may be obtained by addressing The Atlas Portland Cement Company.

After leaving the kiln, the clinker is cooled, crushed, and ground again to a still finer powder, so fine, in fact, that most of the particles are less than 1/200 of an inch in size, and this grinding produces the light gray-colored powder characteristic of "ATLAS" Portland Cement.

It is now placed in storage tanks or stock houses where it should remain for a while to season before it is put into bags or barrels and shipped. The barrels weigh 400 pounds gross, or 376 pounds net. When shipped in bags the weight is 94 pounds per bag, four bags being equal to one barrel.

At the "ATLAS" plants from the time the rock is taken from the quarry until it is packed in barrels or bags all of the work is done by machinery, and a thorough chemical mixture takes place regulated by the experienced chemists in charge of the work.

STORING CEMENT.

Cement should come packed in barrels or in stout cloth or canvas bags and should be stored in a dry place, preferably a house or shed until used, or if no such storage house is available the cement should be placed on a wooden platform raised at least 6 inches above the ground and should be covered so as to exclude water. When used the cement should be free from lumps.

SAND OR FINE AGGREGATE.

The term aggregate includes the stone and sand in concrete and may be classified as fine and coarse. The fine aggregate may be sand or crushed stone or gravel screenings which will pass when dry a screen having ¼ inch diameter holes. If sand is used it should be clean and coarse, or a mixture of coarse and fine grains with the coarse grains predominating. It should be free from loam, clay, mica, sticks, fine roots, or other impurities. Sand should be coarse, that is, it should have a considerable portion of its grains measuring 1/32 to ⅛ inch in diameter and should the grains run up to ¼ inch the strength of the mortar is increased.

Vegetable loam is frequently very injurious to concrete and great care should be taken in selecting and excavating to see that the sand does not contain any vegetable matter. For all important structures the sand should be tested in a laboratory as described in the following paragraphs:

"Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand. To avoid the removal of any coating on the grains which may affect the strength, bank sands should not be dried before being made into mortar but should contain natural mois-

ture. The percentage of moisture may be determined upon a separate sample for correcting weight of the sand. From 10 to 40 per cent more water may be required in mixing bank or artificial sands than for standard Ottawa sand to produce the same consistency."*

"The relative strength of mortars from different sands is largely affected by the size of the grains. A coarse sand gives a stronger mortar than a fine one, and generally a gradation of grains from fine to coarse is advantageous. If a sand is so fine that more than 10 per cent of the total dry weight passes a No. 100 sieve, that is, a sieve having 100 meshes to the linear inch, or if more than 35 per cent of the total dry weight passes a sieve having 50 meshes per linear inch, it should be rejected or used with a large excess of cement."*

Crushed stone or gravel screenings, when used in place of sand, should pass when dry a screen having ¼-inch diameter holes or a screen having 4 meshes to the linear inch and if free from impurities may be substituted for a part or the whole of the sand in such proportions as to give a dense mixture.

COARSE AGGREGATE

Gravel or crushed stone of a hard and durable quality make up the coarse aggregate for concrete. The best materials are trap rock, hard limestone, granite, or conglomerate of size retained on a screen having ¼-inch diameter holes.

Aggregates containing soft, flat, or elongated particles should be excluded from important structures. Stone which breaks into cubical or similar angular forms is much preferable in any case to that which breaks into flat layers because it gives a stronger concrete and one which is more readily placed. Graded sizes of particles, that is, particles varying from small to large sizes, are generally advantageous. Where concrete is used in mass, the crushed stone or gravel may range in size from ¼ inch to that which passes through a 3-inch ring. For reinforced concrete, the particles must be small enough to flow into place around and between the steel bars and into all corners of the forms. For this a maximum size of 1 inch (that is, the largest particle small enough to go through a 1-inch ring), or in other cases a ¾-inch or ½-inch must be used. The material passing the ¼-inch screen may be used as a part of the sand.

If gravel is used instead of crushed stone, it should be of a size to be easily handled and easily placed around the steel if there is steel reinforcement and it should be clean and free from vegetable or other deleterious matter. As in the case of crushed stone, the material below ¼ inch in size should be screened out to be used as sand. Sand and gravel are rarely found mixed in the proper

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*Report of Committee on Reinforced Concrete, 1909, National Association of Cement Users.

proportions in the natural bank, and it is cheaper to screen and remix them in the correct proportions than to use the richer mixture necessary with unscreened material.

Pebbles of graded sizes with the larger sizes predominating are preferable to pebbles of a uniform size because they are more readily mixed and placed.

For important structures and for structures where there will be considerable wear on the concrete, the materials should be carefully selected, but for unimportant structures it is usually sufficient to make two small blocks of concrete, say 6-inch cubes, and place one of these cubes out-of-doors in air for 7 days and the other in a fairly warm room.

The specimen placed in the warm room should be hard enough at the end of 24 hours to bear pressure from the thumb without indentation and it also should whiten out to some extent during this time. The specimen placed out-of-doors should be hard enough to remove from the mold at the end of 24 hours in ordinary mild weather or 48 hours in cold damp weather. At the end of a week test both blocks by hitting them with a hammer. If the hammer does not dent them under light blows such as would be used in driving tacks and the blocks sound hard and are not broken under these blows the sand as a general rule can be used.

WATER.

Water used in mixing concrete should be free from oil, acids, alkalies, or vegetable matter.

PROPORTIONS OF MATERIALS.

The following paragraphs relating to the proper proportions of materials for making concrete are taken from "Concrete Construction About the Home and on the Farm": *

"Concrete is composed of a certain amount or proportion of cement, a larger amount of sand, and a still larger amount of stone. The fixing of the quantities of each of these materials is called proportioning. The proportions for a mix of concrete if given, for instance, as one part of cement to two parts of sand to four parts of stone or gravel, are written 1:2:4, and this means that one cubic foot of packed cement is to be mixed with two cubic feet of sand and with four cubic feet of loose stone.

"For ordinary work, use twice as much coarse aggregate (that is, gravel or stone) as fine aggregate (that is, sand).

"If gravel from a natural bank is used without screening, use the same proportions called for of the coarse aggregate; that is, if the specifications call for proportions of 1:2:4, as given above, use for unscreened gravel (provided it

*Published by The Atlas Portland Cement Company, from whom it can be obtained by making application for same.

contains quite a large quantity of stone) one part cement to four parts unscreened gravel.

"If when placing concrete with the proportions specified, a wall shows many voids or pockets of stone, use a little more sand and a little less stone than called for. If on the other hand, when placing, a lot of mortar rises to the top, use less sand and more stone for the next batch.

"In calculating the amount of each of the materials to use for any piece of work, do not make the mistake so often made by the inexperienced that one barrel of cement, two barrels of sand, and four barrels of stone, will make seven barrels of concrete. As previously stated, the sand fills in the voids between the stones, while the cement fills the voids between the grains of sand, and therefore the total quantity of concrete will be slightly in excess of the original quantity of stone."

The unit of measure is the barrel, which should be taken as containing 3.8 cubic feet. Four bags containing 94 pounds of cement each are equivalent to one barrel. Sand and stone or gravel should be measured separately as loosely thrown into the measuring receptacle.

The following quotation from "Concrete, Plain and Reinforced"* by the well-known authorities, Taylor and Thompson, is printed as a guide to those who wish to build any concrete structure for which specific instructions are not given in the following pages:

"As a rough guide to the selection of materials for various classes of work, we may take four proportions which differ from each other simply in the relative quantity of cement":

(a) A Rich Mixture for columns and other structural parts subjected to high stresses or requiring exceptional water tightness: Proportions—1:1½:3; that is, one barrel (4 bags) packed Portland cement to 1½ barrels (5.7 cubic feet) loose sand to 3 barrels (11.4 cubic feet) loose gravel or broken stone.

(b) A Standard Mixture for reinforced floors, beams and columns, for reinforced engine or machine foundations subject to vibrations, for tanks, sewers, conduits, and other water-tight work: Proportions—1:2:4; that is, one barrel (4 bags) packed Portland cement to 2 barrels (7.6 cubic feet) loose sand to 4 barrels (15.2 cubic feet) loose gravel or broken stone.

(c) A Medium Mixture for ordinary machine foundations, retaining walls, abutments, piers, thin foundation walls, building walls, ordinary floors, sidewalks, and sewers with heavy walls: Proportions—1:2½:5; that is, one barrel (4 bags) packed Portland cement to 2½ barrels (9.5 cubic feet) loose sand to 5 barrels (19 cubic feet) loose gravel or broken stone.

(d) A Lean Mixture for unimportant work in masses, for heavy walls, for large foundations supporting a stationary load, and for backing for stone masonry: Proportions—1:3:6; that is, one barrel (4 bags) packed Portland cement to 3 barrels (11.4 cubic feet) loose sand to 6 barrels (22.8 cubic feet) loose gravel or broken stone.

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*See reference, footnote, page 18.

QUANTITIES OF MATERIALS IN CONCRETE.

In estimating the quantities of cement, sand, and broken stone or gravel in a given volume of concrete or in estimating the volume of mortar or concrete which can be made from one barrel of cement the three accompanying tables will be found useful. The values given in the tables are computed from results of actual experiments and have been checked with concrete laid in large masses.

VOLUME OF CONCRETE MADE FROM ONE BARREL OF PORTLAND CEMENT*

Based on a Barrel of 3.8 Cubic Feet

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Average Volume of Rammed Concrete Made From One Barrel of Cement — Percentages of Voids in Broken Stone or Gravel		
Cem't	Sand	Stone	Cem't	Sand	Stone		50%†	45%‡	40%§
			bbl.	cu. ft.	cu. ft.	per cent.	cu. ft.	cu. ft.	cu. ft.
1	1	2	1	3.8	7.6	75	9.5	9.9	10.3
1	1	3	1	3.8	11.4	51	11.5	12.2	12.8
1	1½	3	1	5.7	11.4	64	12.9	13.5	14.1
1	1½	3½	1	5.7	13.3	55	13.9	14.6	15.4
1	2	3	1	7.6	11.4	75	14.3	14.9	15.5
1	2	4	1	7.6	15.2	57	16.3	17.2	18.0
1	2½	4½	1	9.5	17.1	60	18.7	19.6	20.6
1	2½	5	1	9.5	19.0	54	19.8	20.8	21.8
1	3	5	1	11.4	19.0	61	21 1	22.1	23.2
1	3	6	1	11.4	22.8	52	23.2	24.4	25.6

Note.—Variations in the fineness of the sand and the compacting of the concrete may affect the volumes by 10% in either direction.

†Use 50% column for broken stone screened to uniform size.
‡Use 45% column for average conditions and for broken stone with dust screened out.
§Use 40% column for gravel or mixed stone and gravel.

*Taken by permission from Taylor & Thompson's "Concrete, Plain and Reinforced," copyright, 1905, by Frederick W. Taylor. John Wiley & Sons, New York, publishers.

QUANTITIES OF MATERIALS FOR ONE CUBIC YARD OF RAMMED CONCRETE*

Based on a Barrel of 3.8 Cubic Feet

Proportions by Parts			Proportions by Volume			Volume of Mortar in Terms of Percentage of Volume of Stone	Percentages of Voids in Broken Stone or Gravel								
							†50 Per Cent.			‡45 Per Cent.			§40 Per Cent.		
Cement	Sand	Stone	Packed Cement	Loose Sand	Loose Stone		Cement	Sand	Stone	Cement	Sand	Stone	Cement	Sand	Stone
			bbl.	cu. ft.	cu. ft.	per cent.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.	bbl.	cu. yd.	cu. yd.
1	1	2	1	3.8	7.6	75	2.85	0.40	0.80	2.73	0.38	0.77	2.62	0.37	0.74
1	1	3	1	3.8	11.4	51	2.34	0.33	0.99	2.22	0.31	0.94	2.12	0.30	0.90
1	1½	3	1	5.7	11.4	64	2.09	0.44	0.88	2.00	0.42	0.84	1.91	0.40	0.81
1	1½	3½	1	5.7	13.3	55	1.94	0.41	0.96	1.84	0.39	0.91	1.76	0.37	0.87
1	2	3	1	7.6	11.4	75	1.89	0.53	0.80	1.81	0.51	0.76	1.74	0.49	0 74
1	2	4	1	7.6	15.2	57	1.65	0.46	0.93	1.57	0.44	0.88	1.50	0.42	0 84
1	2½	4	1	9.5	15.2	66	1.52	0.54	0.86	1.46	0.51	0.82	1.40	0.49	0.79
1	2½	4½	1	9.5	17.1	60	1.44	0.51	0.91	1.37	0.48	0.87	1.31	0.46	0.83
1	2½	5	1	9.5	19.0	54	1.37	0.48	0.96	1.30	0.46	0.92	1.24	0.44	0.87
1	3	5	1	11.4	19.0	61	1.28	0.54	0.90	1.22	0.52	0.86	1.17	0.49	0.82
1	3	6	1	11.4	22.8	52	1.16	0.49	0.98	1.11	0.47	0.94	1.05	0.44	0.89

Note.—Variations in the fineness of the sand and the compacting of the concrete may affect the quantities by 10% in either direction.
†Use 50% columns for broken stone screened to uniform size.
‡Use 45% columns for average conditions and for broken stone with dust screened out.
§Use 40% columns for gravel or mixed stone and gravel.
*Quoted from Copyrighted Treatise; see footnote on opposite page.

VOLUME OF PLASTIC MORTAR MADE FROM DIFFERENT PROPORTIONS OF CEMENT AND SAND*

Quantities of Materials per Cubic Yard

Relative Proportions by Volume†		Volume of Compacted Plastic Mortar		Materials for 1 cu. yd. Compacted Plastic Mortar, Based on Barrel of 3.8 Cubic Feet	
Cement	Sand	From 1 cu. ft. Cement, Based on Portland Cement Weighing 100 Lbs. per cu. ft.	From 1 bbl., or 4 bags, Cement, Based on Barrel of 3.8 cu. ft.	Packed Cement	Loose Sand
		cu. ft.	cu. ft.	bbl.	cu. yd.
1	0	0.86	3.2	8.31	......
1	1	1.42	5.4	5.01	0.71
1	1½	1.78	6.7	4.00	0.84
1	2	2.14	8.1	3.32	0.93
1	2½	2.50	9.5	2.84	1.00
1	3	2.86	10.9	2.48	1.05

Note.—Variations in the fineness of the sand and the cement, and in the consistency of the mortar may affect the values by 10% in either direction.

*See reference, footnote, p. 18.

†Cement as packed by manufacturer, sand loose.

RUBBLE CONCRETE.

Rubble concrete is ordinary concrete in which are imbedded large stones, usually of a size that can be handled by one or two men, but in very massive work such as large dams, stones of even greater size as heavy as can be handled with a derrick are used. Only in massive structures such as heavy foundations, dams, retaining walls, or similar works is this form of construction possible and when stones are imbedded in the concrete they should be spaced at least 3 inches from one another and also from the outer surface. About 20 per cent of the total volume of the structure may be replaced by "one-man" and "two-men" stones, and thus a considerable saving in cost is effected in large structures.

MIXING CONCRETE.

Mixing may be done either by hand or machine and the method to be employed is determined principally by the size of the job. If a small amount of concrete is to be made, hand mixing is the more economical, while for large works machine mixers are better and generally cheaper, though in some cases where the mixer must be frequently moved, hand mixing may prove to be the cheaper. A better and more uniform concrete can be made with a good ma-

chine mixer than by hand. The type of mixer should be such as to insure a thorough and uniform mixing of the materials. In any case enough water should be used to make a mushy consistency which requires very little tamping to bring the mortar to the surface.

HAND MIXING.

If hand mixing is employed it should be carefully done on a water-tight platform and should be subjected to thorough supervision. The following directions by Taylor and Thompson for hand mixing will be found useful to those who are inexperienced in this class of work.*

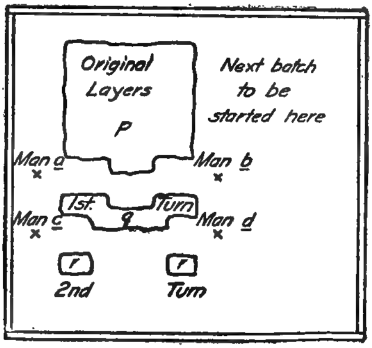


FIG. 1.—POSITION OF MEN AND CONCRETE ON PLATFORM WHILE TURNING.*

"Assume a gang of four men to wheel and mix the concrete with two other men to look after the placing and ramming.

"When starting a batch, two mixers shovel or wheel sand into the measuring box or barrel—which should have no bottom or top—level it and lift off the measure, leveling the sand still further if necessary. They then empty the cement on top of the sand, level it to a layer of even thickness, and turn the dry sand and cement with shovels three times, as described below, after which the mixture should be of uniform color.

"While these two men are mixing sand and cement, the other two fill the gravel measure about half full, then the two sand men take hold with them, and complete filling it. The gravel measure is lifted, the gravel hollowed out slightly in the center, and the mixture of sand and cement shoveled on top in a layer of nearly even thickness.† A definite number of pails are filled with

*See reference, footnote, page 18.
†"Some Engineers prefer to spread the stone on top of the sand and cement, while others prefer to mix the water with the sand and cement before adding them to the stone."

water, and poured directly on the top of these layers, greater uniformity being thus attained than by adding the water directly from a hose. After soaking in slightly the mass is ready for turning.

"The method illustrated in Fig. 1 of turning with shovels materials which have already been spread in layers is as follows:

"Two men, A and B, with square-pointed shovels, stand facing each other at one end of the pile to be turned, one working right-handed and the other left-handed. Each man pushes his shovel along the platform under the pile, lifts the shovelful, turns with it, and then, turning the shovel completely over, and with a spreading motion drawing the shovel toward himself, deposits the material about 2 feet from its original position. Repetitions of this operation will form a flat ridge of the material, on a line with the pile as it originally lay, and flat enough so that the stones will not roll. As soon as, but not before, a single ridge is complete, two other men, C and D, should start upon this ridge, turning the materials for the second time, as shown in the illustration, and forming as before a flat ridge and finally a level pile which gradually replaces the last. A third mixing is accomplished in a similar way.

"Fig. 1 gives the position of the piles as the concrete is being turned. A portion of the original layers is shown at P, the ridge formed by men A and B shoveling from pile P is shown at Q, and the beginning of the ridge formed by men C and D is shown at RR. The third turning is not shown.

"The quantity of water used must be varied according to the moisture in the materials and the consistency required in the concrete. While the opinions of engineers regarding the proper consistency vary widely, it is advisable, the authors believe, for an inexperienced gang to use an excess of water. The rule may be made in hand mixing to use as much water as can be thoroughly incorporated with the materials. Concrete thus made will be so soft or 'mushy' that it will fall off the shovel unless handled quickly.

"After the material has been turned twice, as described, and as soon as the third turning has been commenced, two of the mixers who have finished turning may load the concrete into barrows and wheel to place. They should fill their own barrows, and after the mass has been completely turned for the third time by the other two men the latter should start filling the gravel measure for the next batch.

"If the concrete is not wheeled over 50 feet, four experienced men ought to mix and wheel on the average about 10½ batches in ten hours. This figure is based on proportions 1:2 ½:5, and assumes that a batch consists of one barrel (four bags) Portland cement with 9.5 cubic feet of sand and 19 cubic feet of gravel or stone.

"Assuming that 1.29 barrels of cement are required for 1 cubic yard of concrete, one barrel of cement—that is, one batch—will make 0.78 cubic yard of concrete; hence 10½ batches mixed and wheeled by four men in ten hours are equivalent to 8¼ cubic yards of concrete. This is for the very simplest kind of concreting and makes no allowance for the labor of supplying materials to the mixing platform or for building forms."

PLACING CONCRETE.

In handling and placing concrete, the materials must remain perfectly mixed, the aggregate must not separate from the mortar and the concrete must be rammed or agitated so as to thoroughly fill the forms and surround all parts of the steel reinforcement. Care must be taken to remove all sticks, blocks, shavings, or similar materials from the forms before the concrete is placed and in case new concrete is deposited on a layer that has already set, the old surface should be roughened, cleaned, and drenched with water before the new material is added. In reinforced structures the metal must be placed in the forms and wired or otherwise held rigidly in position before any concrete is laid. It is now generally customary to use wet mixtures and the concrete is usually carried in buckets or in water-tight wheelbarrows. An ordinary whelbarrow load of concrete is about 1.9 cu. ft. If wet concrete is used it can be dropped vertically into place or run through an inclined water-tight chute. Concrete should be wet frequently for a few days after it is laid.

LAYING CONCRETE IN WATER.

Only in exceptional cases should concrete be placed in water and even then the greatest care must be taken to prevent the cement from being washed out. Under no circumstances should it be thrown or placed into water by shovels. In some cases of small construction, the concrete may be deposited in bags, or it may be placed in pails with a board covering the top of the pail and lowered carefully into the water to the bottom. When this has reached bottom, turn the pail upside down and move the board from underneath and carefully raise the pail, allowing the concrete to flow out. Great care must be taken not to disturb the water in which the concrete is being placed nor to touch the concrete before it has set. Under no circumstances should concrete be placed in running water. In large work, it is sometimes placed by means of a tube extending into the water with the lower end near the bottom. By keeping a continuous flow of concrete passing through the tube, the cement will not be separated from the aggregate.

LAYING CONCRETE IN SEA WATER.

For use in sea water concrete must be proportioned to secure maximum density and must be so carefully mixed and placed as to secure an impervious mass. Unless proper precautions are taken in choosing the materials, mixing, and in depositing the concrete there is danger of scaling on the surface of the concrete between high and low water levels.

The remarks just made concerning the use of concrete in sea water are equally true of concrete placed in alkaline soils where the mixture must be of maximum density and must be richer than where used in ordinary soils.

EFFECT OF MANURE.

Manure, because of the acid in its composition, is injurious to green concrete, but after the concrete is thoroughly hardened it satisfactorily resists such action.

FREEZING.

Concrete for thin walls and reinforced concrete structures should not be laid during freezing weather unless concrete is prevented from freezing by warming the materials before mixing and by covering the concrete after it is placed with a thick covering of clean straw, sand, or other suitable material. Common salt is quite frequently used to lower the freezing point of the water used in mixing concrete. A well known rule requires 1 per cent by weight of the salt to the weight of the water for each degree Fahrenheit below freezing point of water.

As one cannot tell in advance how low the temperature is going to fall, an arbitrary amount of salt must be used. Some engineers specify two pounds of salt to each bag of cement, and in case this is not sufficient, three pounds to a bag.

Another method is to mix warm sand and stone with the cement and water in such manner as will bring the entire mixture up to about 75 degrees Fahrenheit, protecting in the early stages of setting, so far as possible, from cold and currents of air.

Heavy walls and foundations where the appearance of the faces is of no importance may be laid in freezing weather.

Concrete sidewalks must not be laid in freezing weather, for the surface will soon scale.

FORMS.

Forms usually are of wood, though in some cases metal is used. They must be strongly built so as to prevent displacement, deflection, or leakage of mortar and they must not be removed until the concrete has set. The time required for setting varies with the condition of the weather, longer time being required in cold or wet weather; with the quality of the cement; and with the amount of water used in mixing. White pine is the best lumber for forms, but cheaper kinds, such as spruce, fir, Norway pine or softer kinds of Southern pine, are frequently used, and green lumber is on the whole better than dry. To secure a smooth surface on the finished concrete, lumber planed on one side must be used; likewise where the forms are to be removed within a day or two, planed lumber must be used, for then the concrete will not stick to the planks and they may be again used without much cleaning.

Forms usually consist of boards held in place by studs braced so as to remain in place. For the boards one or two-inch planks are commonly used

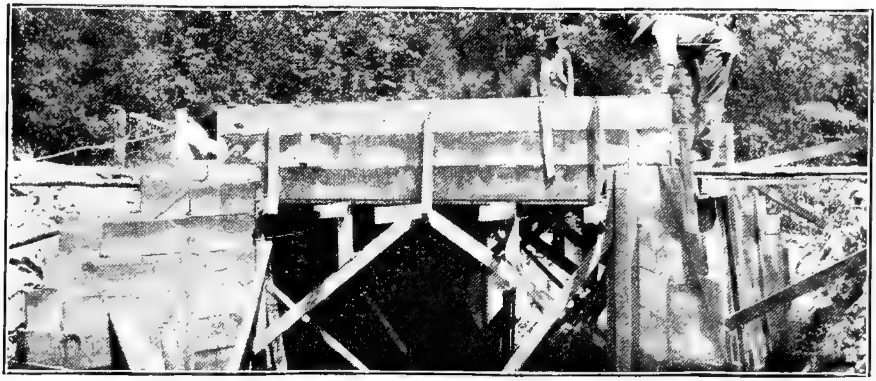


FIG. 2.—FORMS FOR BEAM BRIDGE

and quite frequently tongued and grooved materials are necessary for tight construction. The studs are spaced at distances apart depending upon the consistency of the concrete, the thickness of the wall, and the character of finished concrete surface desired. Wet concrete in large masses is apt to exert considerable pressure against the forms before the cement sets, but with wet concrete less ramming is necessary than with dry mixtures and therefore the forms are less likely to be knocked out of position. With wet mixtures in comparatively thin walls two-inch planking should be supported not over 5 feet apart, while for one-inch boards 2 feet is about the right spacing.

Forms are greased by applying to them a coat of crude oil or soft soap, but if the forms are not to be removed for several weeks no greasing is necessary, though in this case the surfaces of the forms which are to come in contact with the concrete must be thoroughly wet.

PAVEMENT IN CITY OF PANAMA.

BRIDGE NEAR WASCO, ILL.

CHAPTER II.

SIDEWALKS, CURBS, AND GUTTERS.

Concrete is in universal use for sidewalks, curbs, and gutters, and the excellent and permanent qualities of this material are as well shown in these forms as in any other type of construction in which it is used. Sidewalks should be smooth, durable, cheap in first cost, and should present a pleasing appearance. With proper care concrete can be laid to satisfy all these requirements and therefore make a solid durable walk. For curbs alone or for combined curbs and gutters, especially for the streets in residential districts, parks or similar places where neatness of appearance is especially desirable, concrete is being used in many localities almost exclusively. In this chapter are shown methods of construction which are standard and which if followed will produce good results.

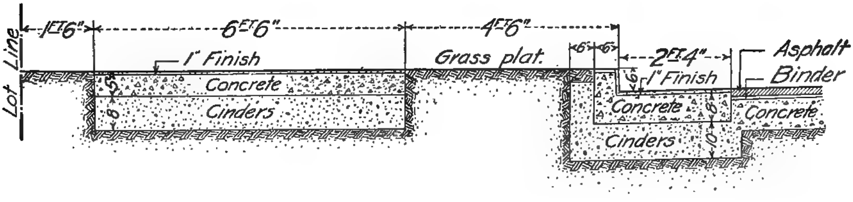


FIG. 3—CROSS SECTION OF SIDEWALK AND COMBINED CURB AND GUTTER.

DIMENSIONS OF WALKS, CURBS, AND GUTTERS.

A first-class walk consists of a foundation of cinders, gravel, or broken stone upon which is laid a layer of concrete called the base and an upper thin layer of mortar called the wearing surface. Granolithic is a common name for concrete walks.

Sidewalks vary in width according to conditions, but the thickness of the concrete is nearly uniform, ranging from four to five inches total thickness including the wearing surface.

In Fig. 3 is shown the section of a sidewalk separated from the curb by a narrow grass plat such as is common in residential streets. The thickness of the concrete is shown as 5 inches, but 4 inches is more commonly used, and if the walk is provided with good foundations and drainage 4 inches is ample in most places. Where the total thickness of the concrete is 4 inches the base should be 3¼ or 3 inches and the wearing surface ¾ or 1 inch, and for a 5-inch walk the base should be 4 inches and the wearing surface 1 inch.

The slope of the surface from the lot line toward the curb should be ¼ or ⅜ inch per foot. For parks and similar locations the walk is usually crowned toward the center.

Curbs are made from 6 to 8 inches wide on top and are generally vertical on the side next to the walk and slightly inclined on the side facing the gutter. The total depth of the curb should be from 12 to 14 inches, and if the street traffic is heavy the curb should set upon a concrete base 12 inches wide and 8 inches thick. Where the curb and gutter are combined, as shown in Fig. 3, the gutter is made 8 inches thick and from 1½ to 3 feet in width. In the case shown the curb has a width on top of 6 inches and tapers down to 6½ inches at the gutter. Sometimes both the inner and outer surfaces of the gutter are made vertical, although it is better to have the front face inclined. The upper outer corner of the curb and the intersection of gutter with face of curb should be rounded off with radii of about 1 inch.

The surface of the gutter should conform to that of the street surface, though in some cities, as for instance Salt Lake City, the upper surface of the gutter is curved in such a manner as to secure greater carrying capacity, the depth of the gutter being 10 inches, whereas it would be only 8 inches were the curve omitted and the slope of the street continued to the curb line. At street corners curbs should be thicker than where straight so as to better withstand shocks from moving vehicles. Where the street traffic is heavy, the upper outer edge of the curb is often provided with a special steel corner imbedded in the concrete as it is laid.

Fig. 4 illustrates a type of concrete curb, gutter, and cross walk construction used considerably in Chicago on streets for ordinary traffic. A cross walk is provided by elevating the street surface near the curbs as shown.

FOUNDATIONS AND DRAINAGE.

A good foundation properly drained is absolutely essential for successful sidewalk construction, and is best made by excavating the soil to a depth of 10 to 15 inches below the level of the finished sidewalk surface, depending on the kind of soil and the locality, so as to give a foundation 6 to 10 inches thick, and after ramming the bottom of the excavation a layer of coarse material such as broken stone, cinders, or coarse sand is placed in the excavation and thoroughly rammed. Drainage and ramming are of the utmost importance. In some cities no foundation is required in soils of clean coarse sand which is porous enough to afford good drainage, while in soils which retain water a foundation of 6 to 12 inches is specified. Fig. 3 shows an 8-inch foundation of cinders under the walk and one of 10 inches under the curb and gutter. Broken stone or gravel should be screened

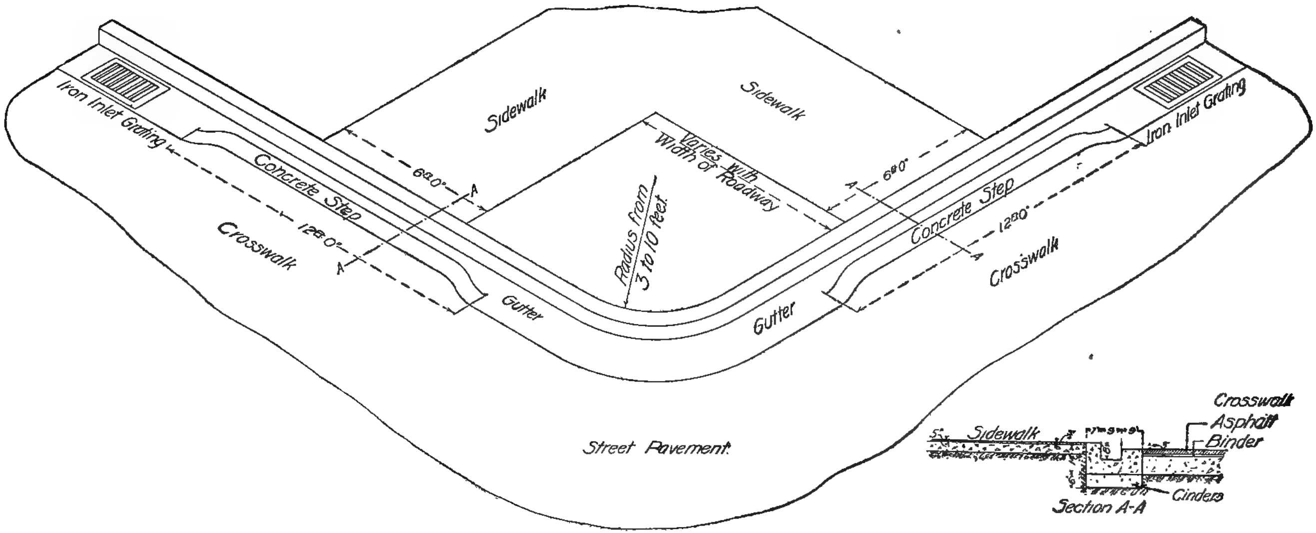


FIG. 4.—CONCRETE CURB AND GUTTER, AND CROSS-WALK CONSTRUCTION.

to remove all fine material and cinders and sand should be wet while being rammed into place. In soils like clay which retain water the foundation should be drained by running occasional drain tiles underneath the soil from the foundation to the gutter, or other suitable outlet. Instead of tile drains small ditches, say 10 by 10 inches in cross section, filled with broken stone may be used.

PROPORTIONS FOR CONCRETE.

Portland cement only should be used.

The concrete for the base should be mixed 1 part "ATLAS" Portland Cement, 2½ parts sand or fine stone which will pass a ¼-inch screen, and 5 parts broken stone or gravel larger than ¼ inch size. Where the quality of the sand and stone require it, these proportions must be slightly changed, and if the sand is not very good 1 part "ATLAS" Portland Cement, 2 parts sand and 4 parts stone or gravel had better be used.

The wearing surface should be mixed 1 part "ATLAS" Portland Cement to 1½ parts sand, and should be of such consistency as not to require tamping, but should be simply floated with a straight edge. The sand here referred to may be either natural bank sand or crushed stone which will pass a ¼-inch screen provided it is from a hard stone which has but little dust.

Another excellent plan is to use 1 part "ATLAS" Portland Cement and ¾ part sand and ¾ part fine crushed stone.

Although 1 part cement to 2 parts fine aggregate is quite frequently used for the wearing surface this mixture is liable to make a surface that will wear sandy.

The combined curb and gutter shown in Fig. 3 is laid on a cinder foundation and the concrete base and 1-inch finish are of the same mixtures as specified for the corresponding parts of the walk.

FORMS.

Forms should be made of clean lumber not less than 2 inches thick, though 1½ may be used if well braced. Fig. 5 shows typical form construction for walks and combined curb and gutter. The walk shown is 5 inches thick and the side forms are 2 by 6 inches, although 2 by 5 inches will do if available. The upper edge must be the exact level of the finished walk. The forms should be of best white pine planed on all sides, should be straight and set to true line and grade. If white pine is too expensive, spruce, fir, or other soft woods may be used. The wooden pegs should be spaced from 4 to 6 feet apart and must be securely driven into the ground so that the forms will not move while concrete is being deposited against them.

The gutter shown as 5 inches thick in the drawing is suitable for streets with light traffic. The curb is 6 inches wide and 11 inches deep with both faces vertical. The side planks are held in place by the wooden pegs and the front plank for the curb is held by clamps and steel dividing plates, the latter serving as spacers as well as dividing plates at the joints. The upper corner of the curb should be rounded to a radius of 1 inch with a tool and the lower corner at the intersection of the gutter and curb should be similarly arranged by rounding off the lower inner edge of the front plank of the curb form.

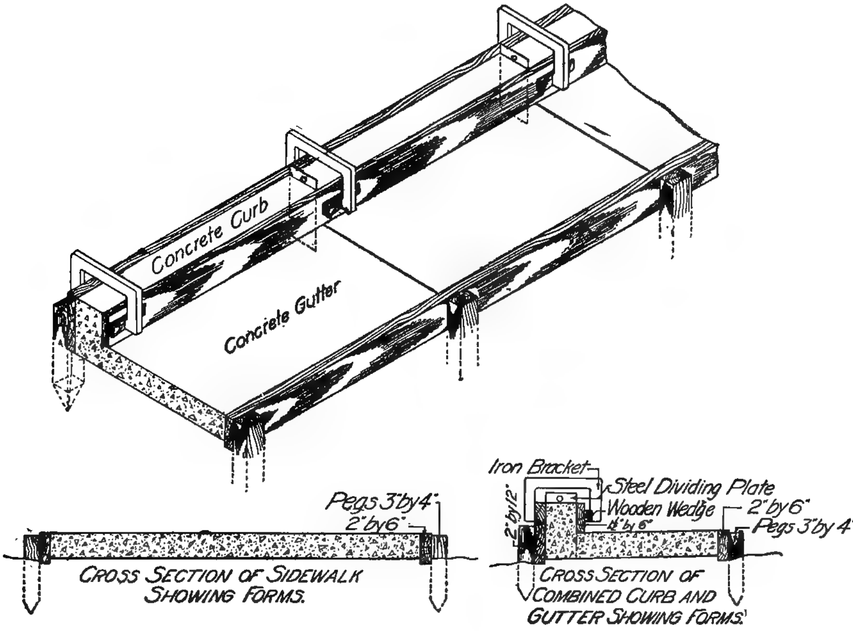


FIG. 5.—FORMS FOR SIDEWALK AND COMBINED CURB AND GUTTER

PLACING CONCRETE.

After having placed and thoroughly rammed the porous foundation, and having carefully set the forms to line, as described above, divide the surface into blocks by cross lines. Mark the dividing lines between the blocks on the side forms by notches and place cross strips from form to form located by these notches. The blocks should be nearly square, and for walks 4 inches in thickness should not be over 6 feet in longest dimension, while for walks 5 inches in thickness 8 feet is about the maximum size. By laying alternate blocks, and then after the concrete has stiffened, removing the cross strips and filling in the blocks between, joints are made so that if the walk heaves

FIG. 6.—CINDER FOUNDATION FOR CONCRETE SIDEWALK.

FIG. 7.—PLACING THE CONCRETE BASE.

slightly, it will crack in the joint and will not show, provided of course the wearing surface is grooved and jointed directly above the joint in the base.

Mix the concrete for the base on a tight platform unless the street pavement is hard and impervious, in which case that can be used for mixing. Make the consistency rather stiff, but wet enough so that the concrete will glisten when it is being mixed, and although holding its shape in a pile, can be compacted and the mortar brought to the surface with comparatively light ramming. See that the surface of the base is exactly one inch below the upper level of the forms, so that the wearing surface will be uniformly one inch thick. To accomplish this, make a straight-edge of 7/8 inch wood notched at each end to fit upon the forms.

As soon as a few blocks of the base have been laid, and before the concrete has set, mix the mortar for the wearing surface. Make this one part "ATLAS" Portland Cement to one and a half parts sand or finely crushed stone and sand mixed. This mortar may be mixed in a mortar box, as it has to be of about the consistency of mortar for laying brick.

To secure good results and prevent the wearing surface from eventually cracking from the base, it is absolutely essential that the mortar be spread before the concrete base has begun to stiffen, for if it is left for several hours or over night the wearing surface is almost sure to peel off in places.

After smoothing the wearing surface with a straight-edge, float it roughly with a plasterer's trowel, and after a few hours, when the mortar has begun to stiffen, float it with a wooden float, and then with a metal float, or, as it is sometimes called, a plasterer's trowel. Neat cement should not be applied to the surface. Just as the final floating is being finished, take a small pointing trowel, and guided by the notches in the side forms and by a straight-edge, placed across the walk, run the trowel down between the blocks so as to form a joint in the wearing surface directly above the joint in the base, and finish this joint with a groover, so as to give it rounded edges. The side edges of the walk are then rounded off with a special jointer, and the surface again finally troweled.

If a roughened surface is desired, a dot roller or a grooved roller may be used. The walk should be protected from the sun for at least four days, and wet down frequently.

Curbs and gutters should be laid in advance of the walk in sections 5 or 6 feet in length and a joint should be left between the curb and the walk. The surface of the gutter and the top and front surface of the curb should be made of a 1-inch layer of mortar the same as used for the wearing surface of the walk. It is important to place the upper part of the curb at the same time with the lower, for the perfect union of the two parts is necessary to keep the curb in position.

FIG. 8.—MIXING MORTAR FOR WEARING SURFACE.

FIG. 9.—TROWELING WEARING SURFACE.

COLORING MATTER.

By selecting a crushed stone of the proper variety a permanent color can be secured for the surface of a walk, some pink granites giving especially pleasing effects. Artificial coloring matter may be secured by the addition of lamp black, ochre, iron oxide, and other materials to the cement, but most of these colors will fade.

MATERIALS FOR CONCRETE SIDEWALKS, FLOORS AND WALLS

Bags of Cement to 100 sq. ft. of Surface area of Concrete Base or of Wall				Bags of Cement to 100 sq. ft. of Mortar Surface			
Thickness, Inches	Proportions			Thickness, Inches	Proportions		
	1:1½:3	1:2:4	1:3:6		1:1	1:1½	1:2
3	8½	6½	4¾	½	3½	2¾	2½
4	11	8¾	6	¾	5	4	3½
5	14½	11	7½	1	7	5¼	4½
6	16¾	13¼	9½	1¼	8¼	6½	5¾
8	22¾	18	12	1½	10	8	6½
10	28¾	21½	15½	1¾	12	9¼	7¾
12	34¾	26½	18½	2	14	11	9

No. of sq. ft. of Concrete Laid with 4 Bags (1 bbl.) of Cement				No. of sq. ft. of Mortar Surface Laid with 4 Bags (1 bbl.) of Cement			
Thickness, Inches	Proportions			Thickness, Inches	Proportions		
	1:1½:3	1:2:4	1:3:6		1:1	1:1½	1:2
3	47	60	83	½	114	146	178
4	36	46	66	¾	80	100	114
5	27	36	52	1	57	73	89
6	24	30	41	1¼	48	60	70
8	17	22	33	1½	40	50	59
10	14	19	26	1¾	33	43	52
12	12	15	21	2	29	36	44

QUANTITIES OF MATERIALS FOR SIDEWALKS.

For the computation of the quantities of cement, sand, and stone required to construct a sidewalk of any given dimensions the accompanying table will be found useful as giving the quantities required to lay 100 square feet of sidewalk. The values given are based on a barrel of 3.8 cubic feet and a coarse aggregate having 45 per cent voids are assumed. In the table allowances have been made for waste. To determine the total volumes required for a walk of given proportions and dimensions the amounts noted for the base and for the wearing surface should be added together. The quantities required will of course vary with the proportions and character of the materials.

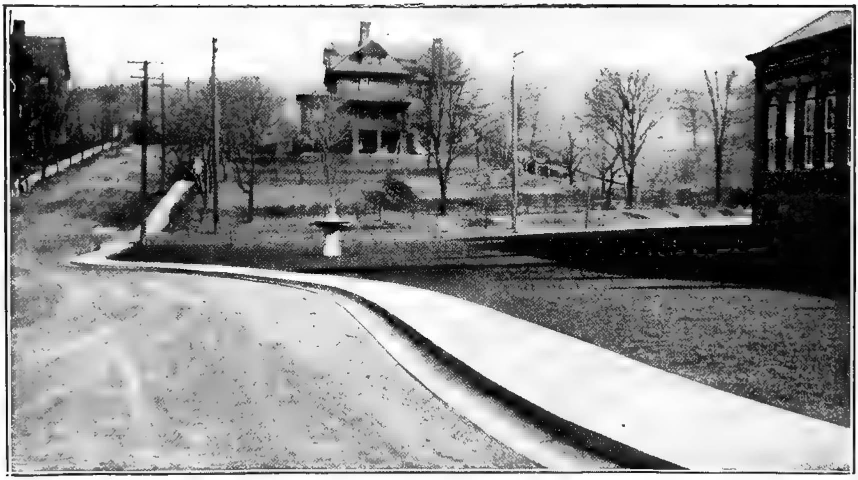


FIG. 10.—CONCRETE SIDEWALK IN SOUTH BETHLEHEM, PA.

COST.

The cost of sidewalks, curbs and gutters varies with the locality, size of the job, and with the character of the soil and materials used. Work finished recently under contract for Salt Lake City shows the following costs to the city. These figures are based on a day's work of eight hours and laborers at $2 per day, form setters $4 per day. Costs given below are per linear foot:

Concrete curb, 6 x 16 inches, without gutter	$0.43
Concrete curb, plain, 6 x 16 inches, with gutter 30 inches wide	0.79
Concrete curb, plain, 6 x 16 inches, with gutter 30 inches wide and curved to special radius	0.85
Concrete curb, 6 x 16 inches, reinforced, without gutter and curved to special radius	0.64
Concrete gutter, 30 inches wide along curb	0.61

Mr. George W. Tillson* gives the cost of concrete walks, 5 inches thick and laid on 7 inches of cinders in Brooklyn, N. Y., as 16½ cents per sq. ft.

Fig. 10 shows a walk built of "ATLAS" Portland Cement in South Bethlehem, Pa., where the current price for walks similar to that shown is from 17 to 20 cents per sq. ft. including curb and gutter. The walk is 4 feet wide, has a 3-inch base of 1:2:4 concrete and a wearing surface of 1:2 mortar, and is laid

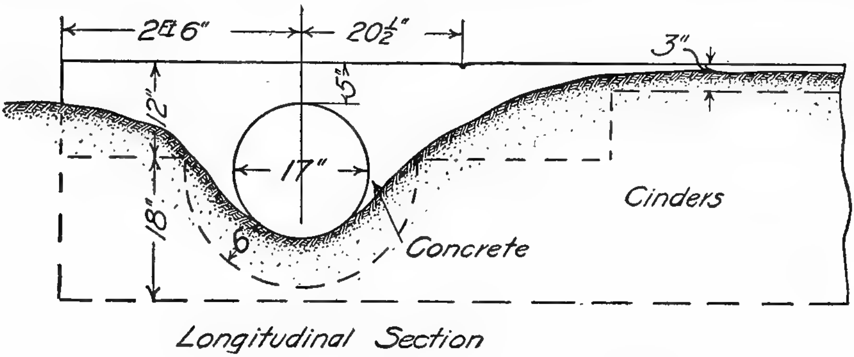


FIG. 11.—CONCRETE CROSS-WALK OVER GUTTER.

on an 18-inch cinder foundation. The front face of the curb is 4 inches high and the gutter is 14 inches wide and 4 inches thick. Street traffic is light so that heavy curbs and gutters are not required at this location.

Fig. 11 and Fig. 12 show a small cross-walk leading from a front walk in a yard over a gutter to a country road. The walk is 4 feet in width and the total length from house to road is 13½ feet. The walk in the yard is 3 inches

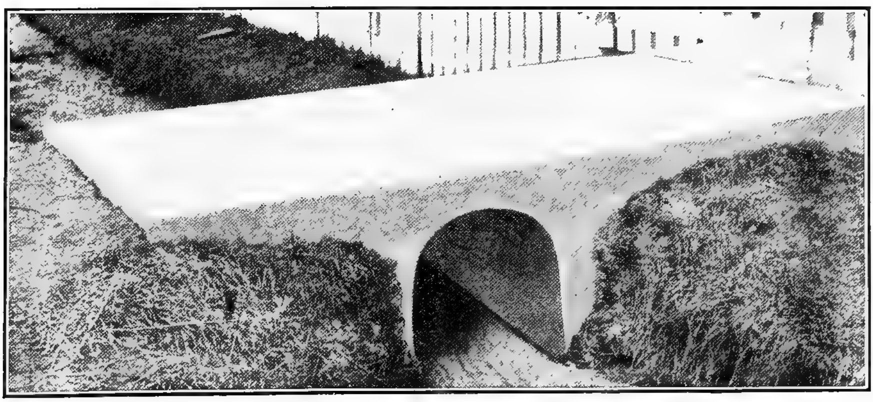


FIG. 12.—CONCRETE CROSS-WALK OVER GUTTER.

*"Street Pavements and Paving Materials," p. 479.

thick, and on each side of the circular opening is 12 inches thick, while under the opening there is a thickness of 6 inches. An 18-inch cinder foundation underlies the whole work. Two cement barrels were used in place of forms and the total cost of the walk and cross-walk was $13.20, or 24½ cents per sq. ft.

VAULT LIGHT CONSTRUCTION.

In Fig. 13 is shown a design for vault light construction supported on

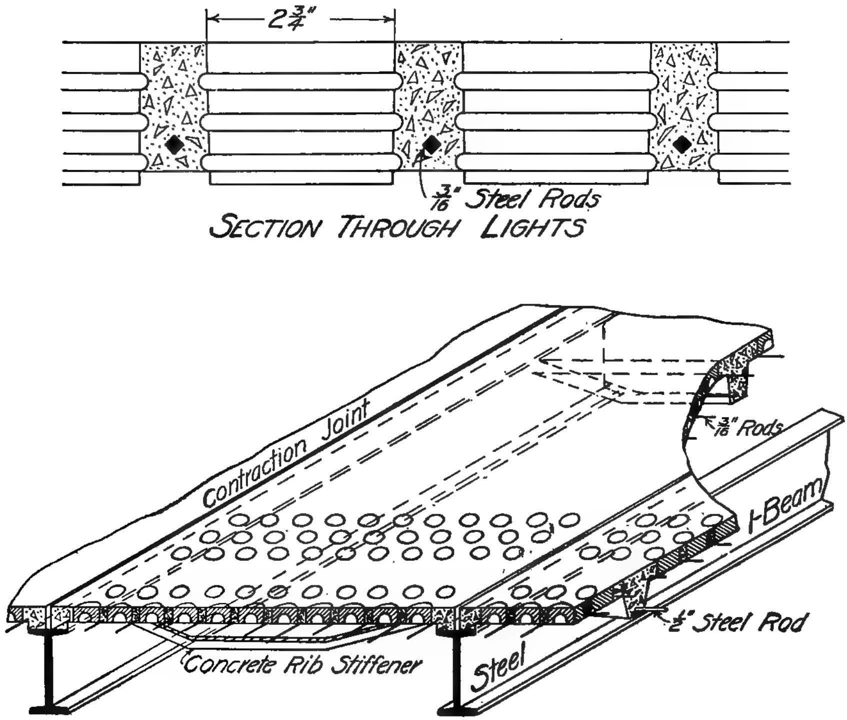


FIG. 13.—TYPICAL VAULT LIGHT CONSTRUCTION.*

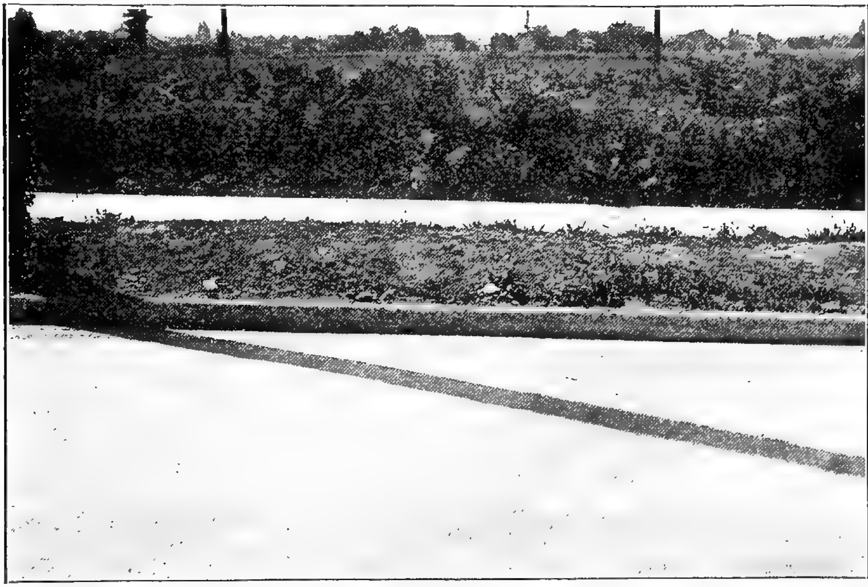
concrete ribs on steel I-beams. The sizes of the concrete ribs and the steel I-beams depend on the spans, and it is necessary to construct the concrete ribs and slab at one time. The glass discs are imbedded in the concrete and admit light to the area below.

*See reference, footnote, page 18.

CHAPTER III.

STREET PAVEMENTS.

The ideal street pavement is durable, noiseless, cleanly, easy to travel on, low in first cost, and built of such material that the maintenance charges are small. Scarcely any material has been found which entirely satisfies these requirements, but some of the pavements of Portland cement concrete which have been built in recent years, where the concrete forms not only the founda-



HASSAM PAVEMENT, PORTLAND, OREGON.

tion but also the wearing surface, are giving thorough satisfaction and approach closely to the ideal for streets where the traffic is not so excessive as to require a stone block.

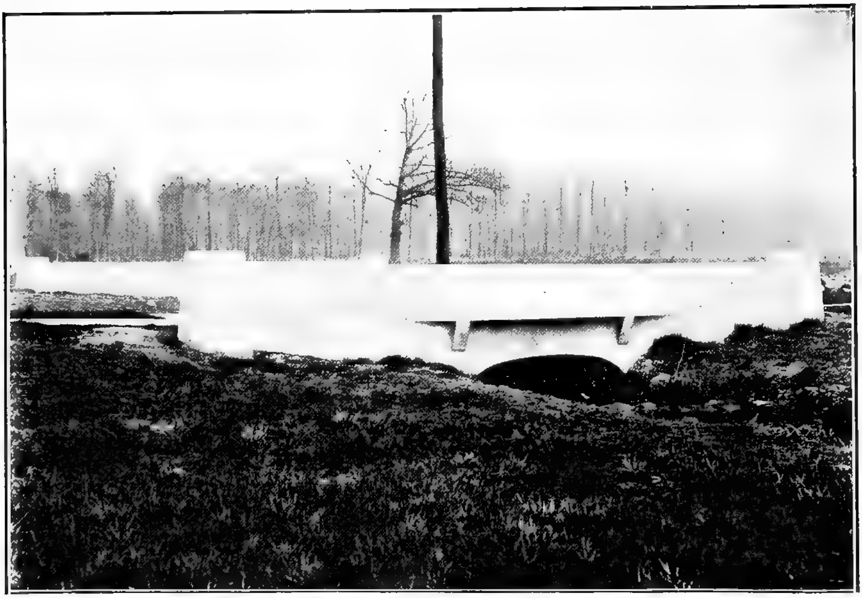
For pavement foundations, concrete is used almost universally in city streets where the wearing surface is asphalt, brick, wooden blocks or stone blocks, and there is no material which can be compared with it for this purpose. Its use for the wearing surface is comparatively new, but it is proving its usefulness to a remarkable degree.

Concrete sidewalks made of a concrete base with a granolithic or mortar wearing surface have been in successful use ever since the beginning of the Portland cement industry. As early as 1894 alleys were paved with concrete in Boston, using methods similar to sidewalk construction except slightly

thicker layers of concrete and surface divisions into small blocks instead of large ones, so as to give better footing for horses.

Probably the first street pavement of concrete was built in Richmond, Ind., in 1903, on Sailor Street, and in 1906, when it was necessary to cut a trench the entire length of this pavement for telephone conduits, the concrete was found so hard that it could be cut only with great difficulty. On the completion of the conduit the pavement was repaired, and in 1908 it seemed to be as good as when laid in 1903.

An alley pavement in Richmond adjacent to the Wescott Hotel, and built



BRIDGE AT HAWORTH, N. J.

in 1896, in which a very heavy traffic is confined to a small space, proved so satisfactory that the street pavement was an outgrowth of it. An examination of this alley in 1908 showed the surface to be in good condition with very little signs of wear.

Concrete street pavements contain the maximum number of desirable qualities as compared with pavements of other materials. They are low in first cost, since the materials of which they are made are within easy reach of all localities desiring good pavements. Practically no section of the country is without stone or gravel good enough for the main body of the pavement,

and if local sand is too poor in quality and freight rates prohibit importing good sand, fine crushed stone may be used in its place. "ATLAS" Portland Cement is within the reach of every section of the country.

The quality of materials and workmanship for concrete pavements is of greater importance than in almost any other form of concrete construction. The aggregate must be chosen with extreme care, the cement must be of a first-class standard brand, the proportioning of the materials must be accurate, and the consistency right. Concrete roadways require expert workmanship but no more so than the laying of other forms of pavement. The methods of laying and the materials to employ are best understood by reference to the descriptions given in the pages which follow of pavements which have proved successful. Too great stress cannot be laid upon the matter of a first-class aggregate for the wearing surface; if this cannot be obtained concrete street paving should not be attempted.

The maintenance cost of concrete pavements is very low. They are not injured by the elements or by materials which attack some forms of pavement. The cost of maintenance of a pavement includes the cost of keeping it clean and concrete can be easily cleaned by flushing the street with water, since this does not in the least injure the quality of the concrete whereas with some other pavements constant flushing is extremely injurious.

The item of smoothness is to a large degree within the control of the builder of the concrete pavement; for the surface can be made perfectly smooth or it can be left with any degree of roughness by grooving the surface or otherwise. Clearly, on a steep grade the pavement should be left so that horses can get a foothold and on curves so that automobiles will not slip. Both of these conditions can be met by grooving or roughening the wearing surface of the concrete.

A wagon running over a concrete pavement makes less noise than running over a stone block or other similar pavement having many joints. Another advantage of these pavements is that there are very few places where dust and dirt can collect.

Summing up then the advantages of concrete pavements it is seen that they offer very little resistance to moving vehicles, afford good foothold for horses and prevent slipping of fast moving automobiles, are clean, can easily be kept free from dirt, and are not very noisy. A pavement combining all these desirable qualities is certainly one that should commend itself to those in charge of construction and maintenance of our city streets.

CONCRETE STREET PAVEMENT FOUNDATIONS.

Concrete was first used in foundations for street pavements in New York City in 1888. At the present time nearly all cities require that concrete foundations shall be laid under all classes of pavements. It is well understood

that the success of any pavement depends largely upon its foundation. To insure a good foundation the subsoil should be properly shaped and graded and then thoroughly rolled with a steam roller weighing not less than 10 tons. When rolling the sub-grade care should be taken to remove all timbers or other matter which may decay and leave space underneath the foundation. All ditches or holes must be filled and any soft material removed and replaced by good, dry gravel or similar materials.

PROPORTIONS OF CONCRETE FOR STREET FOUNDATIONS.

The proportions of materials for concrete to be used in foundations for pavements such as granite blocks or asphalt depend upon the local conditions. The heavier the traffic the stronger should be the foundation. The proportions most common are 1 part "ATLAS" Portland Cement, 3 parts sand, and from 5 to 7 parts broken stone or gravel. In most cases 1 part "ATLAS" Portland Cement, 3 parts sand, and 6 parts broken stone or gravel makes a first-class foundation. The thickness of foundations of Portland cement concrete should be 6 inches. The surface of the concrete should be kept wet for a few days.

One square yard of concrete foundation 6 inches thick will require 1/6 of a cubic yard of concrete. If the mixture is 1:3:6, as previously specified, the quantity of cement, sand, and broken stone in a square yard of foundation can easily be determined from the tables of quantities in Chapter I, page 19, by dividing the quantities given by 6. Thus, for 1 square yard of 6-inch foundation made of a 1:3:6 mixture there will be required 0.185 barrels of cement, 0.078 cubic yards of sand, and 0.157 cubic yards of stone. These figures are based on average conditions, that is, 45 per cent of voids in the broken stone. Quantities may also be found still more directly from table in Chapter II, page 27.

COST OF CONCRETE FOUNDATIONS IN PLACE.

The cost of concrete foundations for pavements varies greatly with the proportions used and with the cost of the materials and labor. The cost ranges from 75 cents to $1.50 per square yard for the usual thickness of 6 inches. The following is an estimate for the cost of 1 cubic yard of 1:3:6 concrete in place making 6 square yards of finished foundation. For other prices of materials and labor the items may be varied accordingly.

Portland Cement, 1.11 barrels, $2.00	$2.22
Sand, 0.47 cu. yd., 75 cents	0.35
Broken Stone, 0.94 cu. yd., $1.75	1.65
Labor with wages at 20 cents per hour	1.15
Cost of 1 cubic yard, that is, 6 square yards of foundation of 1:3:6 concrete in place	$5.37
Cost of 1 square yard of 6-inch foundation	0.90

MIXING OF CONCRETE.

Machine mixing gives a better quality of concrete than hand mixing, but unless a large area is to be concreted and the machinery is very carefully selected and arranged, hand mixing is apt to be cheaper and is therefore more commonly used. For hand mixing a tight matched board or metal platform should be used, and the methods should conform to those outlined in Chapter I. The consistency of the concrete may be somewhat dryer than for reinforced concrete work, but should be wet enough so that the mortar will flush the surface with a very little ramming.

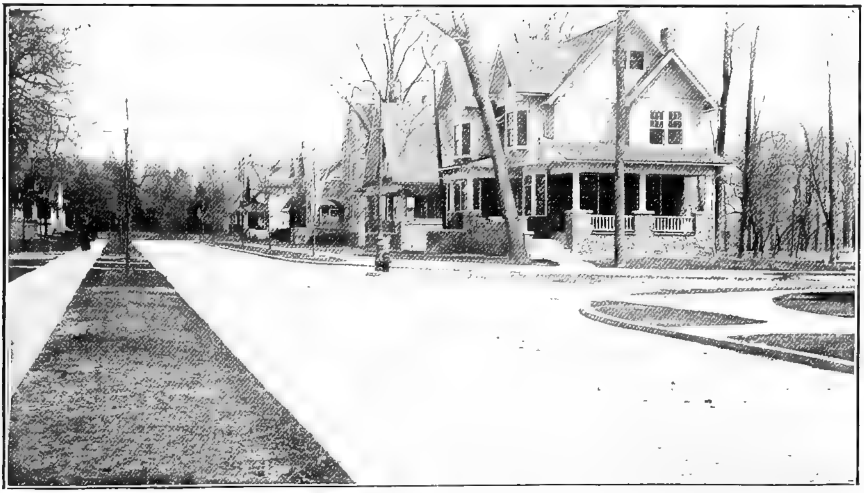


FIG. 14.—CONCRETE ROAD AT FLUSHING, L. I., N. Y

GANG FOR HAND MIXED CONCRETE.

To illustrate the arrangement of a gang in street pavement foundation work, the following example is taken from actual practice:*

Gang for a 6-inch foundation for a street pavement, where the sand and cement were made into a mortar and spread on to the stone, and where two mixing platforms were used, one on each side of the street, with a mortar box between them.

"One foreman.

"Two men mixing mortar in one mortar box.

"Four men shoveling stone alternately into two measuring boxes.

"Four men working alternately on the two mixing platforms, spreading mortar on stone, mixing concrete, and shoveling to place.

"Three men leveling and ramming concrete, and also assisting to shovel to place.

"One man carrying water and doing other odd work.

"The total quantity of concrete in proportions 1:2:5 laid per day of ten hours averaged from 40 to 46 batches or 29 to 33 cubic yards per day for the gang. The gang was not quite up to the average, for under given conditions they ought to have turned out regularly 34 cubic yards per day of ten hours."

***See reference, footnote, page 18.**

CONSTRUCTION OF FOUNDATIONS.

The whole operation of mixing and depositing concrete in pavement foundations should be carried on as quickly as is possible with thoroughness. Concrete which has been mixed and has set or hardened to any extent should not be allowed to be used in the foundation. Wherever possible the concrete should be laid entirely across the street without longitudinal joints. Boards set to proper elevation and curved on the upper edge to conform to the cross section of the foundation are set across the street and between these forms the concrete is laid.

When connection is to be made with any section which has been previously laid and which is partially or wholly set the edge of such section must be broken off so as to be vertical, and must be freed from dirt and properly wet before fresh concrete is laid against it. No carting, wheeling, walking or bicycle riding should be allowed on the concrete until it has hardened.

The top surface of all concrete foundations should be left rough so as to better hold the wearing surface which is placed upon it. Expansion joints may be left at intervals not over 100 feet lengthwise of the street. They can be made best by setting in the concrete a 1-inch board upright on its edge across the street from the curb to curb and after the concrete is sufficiently hardened the board is removed and the space filled with coarse or fine gravel. Expansion joints are especially necessary near a change in grade of the street where expansion from heat may cause the pavement to buckle upward.

CROWNING OF ROADWAYS.

The finished surface of all roadways should be higher at the center than at the gutters to afford good drainage. Although engineers do not entirely agree as to the proper amount of this crowning, practically all agree that the upper surface of the sub-grade and of the foundation should be crowned to conform to the upper finished surface of the street pavement. Crowning is necessary on all streets and for all materials and the smallest crown which will properly drain the street surface is best.

The top of the sub-grade is always below the surface of the finished pavement by an amount equal to the thickness of the pavement and its cushion, if any, plus the thickness of the concrete foundation.

In addition to crowning of the surface the street should have a longitudinal grade so that water can be carried off. This grade should not be less than 0.3 feet or 4 inches in 100 feet for hard materials such as pavements of concrete or good macadam. Where the street is level the longitudinal drainage must be secured by giving a grade to the gutters between catchbasins. This necessitates varying the crown along the street.

For widths of roadways between curbs of 24, 30, 36, 48, and 60 feet the crown should be 3, 4, 5, 6, and 8 inches respectively; the inches given being the difference in elevation of the finished wearing surface at the center of the street and at each curb.

The cross section of the street surface is curved and points on this curve can most easily be located by driving stakes at the center of the street, at each curb and at points 1/3 and 2/3 distant from the center to the curb on either side. The tops of these stakes can be located in the following manner: Stretch a string across the street so that it will be level at the proper elevation of the upper finished surface of concrete foundation at the center of the roadway. Compute the ordinates from the string to the elevation of the finished surface of foundation at points 1/3 and 2/3 of the distance from the center toward each curb. The ordinate to be measured down at the 1-3 point nearest the center is equal to 1/9 of the amount of crown determined upon and the ordinate to be measured down at the 2/3 point from the center is 4/9 of the total crown. This is illustrated in the accompanying table. Thus,

TABLE OF OFFSETS FOR CROWNING STREETS OF VARIOUS WIDTHS.

Width of Roadway Between Curbs	Crown	Distance From Center of Roadway	Vertical Offset	Distance From Center of Roadway	Vertical Offset
Feet	Inches	Feet	Inches	Feet	Inches
24	3	4	1/3	8	1 1/3
30	4	5	4/9	10	1 7/9
36	5	6	5/9	12	2 2/9
48	6	8	2/3	16	2 2/3
60	8	10	8/9	20	3 5/9

for a roadway 24 feet wide having a crown of 3 inches the elevation of the finished surface of foundation at points 4 feet on either side of the center should be 1/9 of 3 inches, that is, 1/3 inch below the level string, which corresponds with the elevation of the upper surface of concrete foundation at the center. At points 8 feet out on either side of the center of the roadway the elevations of the finished surface of foundation should be 4/9 of 3 inches, or 1 1/3 inches, below the string. The gutter of course would be 3 inches below the surface at the center where the crown is 3 inches as here assumed. The grade of the sidewalk next to the property line is frequently made the same as the center of the street.

Transverse rows of stakes similar to those just described are placed every 10 to 25 feet apart lengthwise of the street. Of course, these stakes should be driven in after the sub-grade is thoroughly rolled and shaped so that they will be parallel to the finished surface of street.

The curbs should always be set to line and grade before the foundation for the pavement is laid.

FOUNDATIONS UNDER STREET RAILWAY TRACKS.

When a street or a portion of a street under improvement is occupied by street railway tracks and the tracks are removed during construction work, the excavation of that portion of the street occupied by the tracks should be made to a depth of 6 inches below the bottom and 6 inches beyond the ends of the ties. The remainder of the excavation must correspond in depth to that required for the ordinary pavement. The concrete along the track is then laid to a thickness of 6 inches below the bottom of the ties. The ties and rails are set in place upon this layer and brought to true line and grade. Additional concrete should be tamped under and around the rails and thoroughly grouted with a grout made of 1 part "ATLAS" Portland Cement to 2 parts clean, sharp sand. In case concrete beam construction is used, that is, where a rectangular beam of concrete is laid longitudinally under each rail, the excavation must conform to special plans for the track construction.

For sheet asphalt pavements the top of the concrete foundation should be parallel with and 3 inches below the finished surface grade. For stone block pavements to allow for 6-inch block and 2-inch sand cushion the top of the concrete is 8 inches below the finished surface of the pavement. Brick pavements are usually 4 inches thick and are laid with a 2-inch sand cushion between the bottom of bricks and top of concrete foundation so that the concrete is 6 inches below the finished grade.

CONCRETE PAVEMENTS.

The use of concrete for the wearing surface of a pavement as well as for the foundation is comparatively recent. The examples of these pavements already built have proved so successful that the increase in this class of construction will undoubtedly be very rapid. If, as has been indicated, proper care is used in the selection of the materials and in the workmanship, such pavements will prove satisfactory and durable.

Concrete pavements have been successfully built by several cities as described in the pages which follow, and patented types of pavement, the Blome and the Hassam, have also been laid in various places. Pavements built in Richmond, Ind., and other cities, have been made by similar methods to those employed for first-class sidewalk construction, using a compacted and well drained foundation of concrete and a mortar wearing surface. The Blome pavement is similarly made with a concrete foundation and a concrete wearing

surface, using specially selected materials and having the surface divided into blocks. The Hassam pavement usually consists of well compacted layers of broken stone with the voids filled with Portland cement grout and thoroughly rolled.

FIG. 15.—BLOME GRANITOID PAVEMENT, OHIO STREET, CHICAGO.

ESSENTIALS OF A CONCRETE PAVEMENT.

In order that a concrete pavement shall prove satisfactory the following essentials must be adhered to:

(1) Thoroughly compacted sub-foundation.
(2) Foundation (unless the soil is very porous) of porous materials rolled or otherwise compacted.
(3) A base of first-class Portland cement concrete.
(4) A wearing surface composed of a standard Portland cement and a carefully selected aggregate.
(5) Expert and very careful workmanship.

The fine aggregate for the surface layer is of the utmost importance. Perhaps the best material is crushed granite or crushed trap whose particles pass a ¼-inch sieve and which contains scarcely any dust. Sand may be used pro-

vided it is of exceptionally good quality, coarse, clean, free from clay or other fine matter, and absolutely free from vegetable loam. In natural sand the percentage of dust passing a sieve having 100 meshes per linear inch might well be limited to 3 per cent.

BLOME CO. GRANITOID CONCRETE PAVEMENT.

Pavements made entirely of concrete are coming more and more into general use as the true strength and worth of concrete is becoming better known and understood. One of the all-concrete pavements is known as the Blome Co. Patented Granitoid Pavement and is laid under patents owned by the Rudolph S. Blome Company of Chicago. As previously stated the Blome Co. Granitoid pavement consists of a lower layer of concrete serving as a base and an upper thinner layer of richer concrete forming a wearing surface; the two layers being laid so as to secure a perfect union, thus forming a monolith. The upper surface is grooved to give a good foothold for horses.

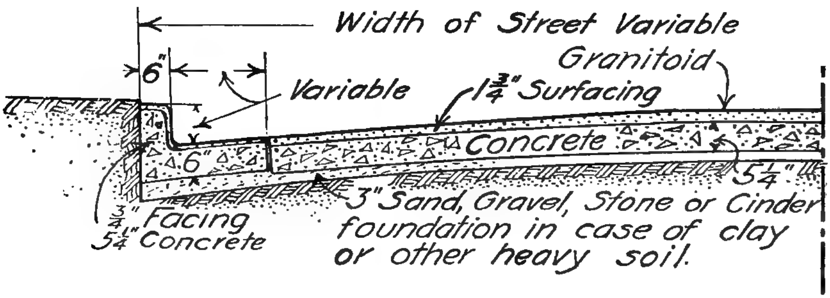


FIG. 16.—STANDARD SECTION BLOME CO. PATENTED GRANITOID PAVEMENT.

Fig. 16 shows a standard section of the Blome Co. Granitoid Pavement. It consists of a 5¼-inch thickness of concrete with a 1¾-inch surface of a richer concrete, the two layers being laid so as to give it thorough union. The drawing shows a foundation of sand, gravel, broken stone or cinders which is necessary where the soil is clay or hard pan or in fact in any soil except a porous sand or gravel. Expansion joints, ½ inch wide, are left along the gutters or curbs.

The granitoid pavement has been laid in many places and has given very good satisfaction. It presents a gritty surface and affords an excellent foothold for horses. On wet slippery streets horses travel more freely and easily on the granitoid pavement than on other more smooth and equally hard pavements. Granitoid has been used successfully on 8 per cent grades at Knoxville, Tennessee; on streets in Michigan where the temperature falls at times

to 40 degrees below zero; and on streets in the South where the pavement is subjected to intense heat. Granitoid pavements have demonstrated that when properly laid concrete is not seriously affected by temperature.

GENERAL SPECIFICATIONS FOR THE BLOME COMPANY GRANITOID CONCRETE BLOCKED PAVEMENT.

The following general specifications have been furnished through courtesy of the Rudolph S. Blome Company of Chicago.

PREPARATION OF SUB-GRADE.—The street shall be graded (excavated or filled as the case may be) to sub-grade, including compacting and rolling by means of a heavy steam roller, and all slopes, contours and other shaping required in the finished pavement shall be formed and provided for in said sub-grade, so that the foundation and pavement hereinafter specified will be uniformly of the same thickness throughout. The contractor to use extreme care to remove all spongy material or other unsuitable or vegetable matter that may be in the way of making this improvement a permanent one.

The contractor will bid with the strict understanding that he or they must use all necessary precautions in preparing the sub-grade, so as to support the pavement permanently, and so that the pavement shall remain at the original grade for a period of five years. This clause shall not be waived on account of any trenches or holes dug in the street by any corporation or private party, prior to the laying of the pavement.

FOUNDATION.—Where the natural soil is of sandy or gravelly nature, no other foundation will be required, but where the natural soil is clay, the contractor shall grade for and provide a foundation of sand, gravel, crushed stone or other suitable material, and which foundation after having been flooded and compacted, satisfactory to the engineer, shall be not less than 3 inches thick.

MATERIALS.—Samples of the cement which is proposed to be used in the work shall be submitted to the engineer in such quantities and at such time and place as will enable him to make all required tests.* The engineer reserves the right to reject without recourse any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All the cement to be used must be delivered on the work in approved packages, bearing the name, brand or stamp of the manufacturer. It shall be thoroughly protected from the weather until used in such manner as may be directed.

SAND.—All sand shall be clean, dry, free from dust, loam and dirt, of sizes ranging from 1/8 inch down to the finest, and in such proportions that

*Specifications for the cement are also included.

the voids, as determined by saturation, shall not exceed 33 per cent of the entire volume, and it shall weigh not less than 95 pounds per cubic foot. No wind drifted sand shall be used.

CRUSHED STONE.—All crushed stone used in making the concrete shall be of the best quality of limestone, trap rock or granite, clean, free from dirt, broken so as to measure not more than 1½ inches and not less than ¼ inch in any dimension. The stone when delivered on the street shall be deposited on flooring and kept clean until used.

GRAVEL.—If gravel is used, same to be perfectly clean gravel, free from all loam and foreign substances, and the same size as that specified herein for crushed stone.

MIXING AND LAYING OF CONCRETE AND FORMATION OF THE BLOME COMPANY GRANITOID BLOCKING.

The concrete and blocking hereinafter specified shall be constructed and manipulated according to the Blome Company patents and processes, using materials mixed in the proportions and laid as hereinafter specified.

The pavement shall consist of 5¼ inches of concrete, and surface blocking 1¾ inches, making a total of 7 inches, exclusive of foundation.

After the sub-grade and foundation have been prepared as hereinbefore specified, there shall be deposited concrete composed of 1 part of Portland cement, 3 parts sand, and 4 parts of crushed limestone, trap rock, or clean gravel. These materials to comply with the requirements hereinbefore set forth and shall be mixed by special mixing machine suitable for the purpose to be approved by the engineer and shall be mixed at least five times before being removed from the mixer. The concrete shall be thoroughly tamped in place, and shall be 5¼ inches thick, uniformly at all points, after having been compacted, shall be laid in sections with expansion joints, all as per the Blome Company patents and shall follow the slopes of the finished pavement so that the surface blocking is and shall be uniformly of the same thickness at all points.

SURFACING MATERIAL.—After the concrete has been placed and before it has begun to set, there shall be immediately deposited thereon the Granitoid Blocking which shall be 1¾ inches in thickness to be composed of two parts of the hereinbefore specified Portland cement and three parts of clean, crushed granite, trap rock, hard stone, crushed gravel, crushed boulders, or other similarly hard materials shall be screened with all the dust removed therefrom utilizing the following composition of this material.

Fifty per cent of the granite, trap rock, hard stone, crushed gravel, crushed boulders or other similarly hard materials to be what is known as ¼-inch size,

30 per cent of the 1/8-inch size, and 20 per cent of the 1-16-inch size with all finer particles removed. These proportions of sizes are extremely essential and must be kept absolutely accurate as in this lies one of the essential requirements to produce proper results. This material to be mixed with cement thoroughly and after being wetted to a proper consistency and deposited on the concrete shall be worked into brick shapes of approximately 4½ inches by 9 inches with rectangular surface similar to paving blocks, all as per special method and utilizing grooving apparatus as employed under the Blome Company patents. The pavement shall be sloped in a manner as required by the City Engineer.

Should there be any part or parts of this pavement when completed where the slopes, contours, etc., have not been carried out in true manner then under this specification the contractor will be required to take up such part or parts down to the foundation and replace same to the proper level without expense of any kind to the city.

EXPANSION JOINTS.—The contractor for the work above specified shall also be required to provide for expansion joints across the pavement at such locations as may be necessary, which expansion joints shall extend through the blocking and concrete and shall be filled with a composition especially prepared for the purpose according to the Blome Company patents. These expansion joints shall be constructed in an extremely careful manner under specific direction of the City Engineer.

PATENTS.—All fees for any patent invention, article or arrangement or other apparatus that may be used upon or in any way connected with the construction, erection, or maintenance of the work or any part thereof, embraced in the contract on these specifications shall be included in the price stipulated in the contract for said work, and the contractor or contractors must protect and hold harmless the city against any and all demands for such fees or claims.

GUARANTY.—Upon the completion of the contract, the contractor shall furnish a satisfactory surety company bond executed by one of the Surety Companies in good standing in the State of ————, guaranteeing the pavement mentioned against settlements, upheavals, disintegration and the results of faulty workmanship, and the use of materials of improper quality for and during the period of five years from and after the date of completion of the pavement.

It is to be expressly understood that the above-mentioned pavement shall satisfactorily withstand all severe usage to which same will be subjected during and for the period named above.

BIDDERS' ATTENTION.—The attention of the bidders is called to the following copy* of agreement in the offices of the City Clerk for furnishing

*Not here given.

necessary materials and mixtures for laying the surfacing material of the contemplated pavements and for the allowance of the uses of certain patented processes owned and controlled by the Blome Company and for the expert advice which will be furnished, which agreement forms a part of these specifications and which must be considered as a requirement by prospective bidders in the making up of their proposals on the contemplated work.

FIG. 17.—BLOME CO. GRANITOID PAVEMENT, KNOXVILLE, TENN.

COST OF BLOME CO. GRANITOID PAVEMENT.

The cost of this pavement varies greatly, depending upon location, quantity of work, costs of the various materials and labor. The price ranges from \$1.50 to \$3 per square yard, not including excavation or grading. Its use compares favorably in cost with brick, asphalt, or creosote or wooden blocks on concrete foundations.

In Knoxville, Tenn., the same granitoid laid in accordance with methods previously described cost \$1.88 per square yard in place, exclusive of the grading, which varied from 15 to 20 cents per square yard of pavement, making the total cost of finished pavement from \$2.03 to \$2.08 per square yard.

In New Haven, Conn., the Blome pavement has been laid at \$2.25 per square yard.

A piece of granitoid block laid on 48th Avenue, Hawthorne, Ill., in the fall of 1904, was in very good condition when examined in January, 1909. This pavement is 7 inches thick and cost $3 per square yard exclusive of excavation or grading.

HASSAM PAVEMENT.

Hassam pavements are laid in the form of a grouted macadam street or as a granite block pavement on a grouted macadam foundation. In each case the work is done in a manner peculiar to this type of pavement.

FIG. 18.—HASSAM PAVEMENT, BIDDEFORD, MAINE.

HASSAM GROUTED CONCRETE PAVEMENT.

The Hassam pavement as usually laid consists of a properly compacted sub-grade upon which is placed a layer of broken stone thoroughly rolled to a thickness of six inches and made to conform to the grades and contour of the street. After this stone has been firmly compacted by rolling and the voids reduced to a minimum it is grouted with a Portland cement grout made of one part cement and two parts sand. This grout is poured upon the stone until all the voids are filled and the grout flushes to the surface. The rolling is continuous during the process of grouting. Upon this surface is placed a very thin layer of pea stone which is spread over the entire area of the roadway, grouted and rolled, the rolling to continue until the grout flushes to the surface. Expansion joints are left along the curbs. The data given above was taken from the specifications of the Hassam Paving Company who have a patent on this pavement.

Hassam pavement has been laid upon a grade of 7 per cent in Biddeford, Maine.

LONG ISLAND MOTOR PARKWAY.

The automobile is rapidly changing the conditions governing the building of improved streets and highways. This is particularly noticeable along the suburban highways where it is possible to run automobiles at high speeds. Concrete pavement seems to be well adapted to meet the conditions imposed by this particular class of traffic. An example of the Hassam type of pavement for automobile traffic is the Long Island Motor Parkway. The paved portion of this parkway is several miles in length and "ATLAS" Portland Cement was used throughout.

FIG. 19.—CONSTRUCTION OF LONG ISLAND MOTOR PARKWAY.

The method of construction was as follows: The sub-grade was shaped and rolled with a 10-ton roller. A 2½-inch layer of broken stone 1½ to 2½ inches in size was then spread upon the sub-grade and upon this broken stone a wire fabric reinforcement was laid over the entire width of the roadway and the separate sheets overlapped as shown in the photograph. A layer

of broken stone was then spread upon the fabric so as to conform to the cross section of the roadway and to give a pavement five inches in thickness after rolling.

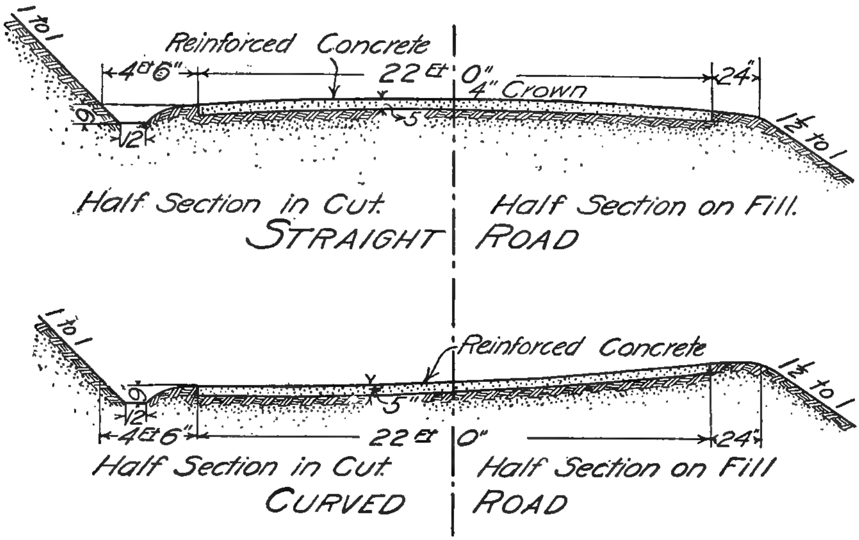


FIG. 20.—TYPICAL CROSS SECTION OF LONG ISLAND MOTOR PARKWAY.

After the ballast was placed on the reinforcement it was thoroughly rolled and compacted with a 10-ton roller. Portland cement grout made with one part of "ATLAS" Portland Cement and two parts sand was mixed in a mechanical mixer and poured upon the surface of the rolled ballast until all the voids were filled and until the grout flushed to the surface after rolling. The grout was colored with lampblack to slightly darken the finished pavement. After the grout had been poured and rolled a thin layer of pea stone was spread, grouted, and the surface again rolled as before.

The finished pavement was given a rough surface by brooming so as to form very small ridges at right angles to the length of the roadway. Care was taken to complete all rolling after grouting each section before a sufficient period of time had elapsed to allow the cement to take its initial set. Automobiles were allowed on the finished pavement ten days after completion.

This pavement was laid by the Hassam Paving Company of Worcester, Mass. No provision was made for expansion or contraction, but as previously stated the roadway was reinforced with wire fabric. Fig. 20 shows typical sections of the parkway. The upper drawing represents construction where the road is straight, and the lower where the road is on a curve.

COST OF HASSAM PAVEMENT.

A Hassam pavement was completed in Watertown, Mass., during October, 1908, at a cost of $1.85 per square yard. The pavement consists of a 6-inch thickness of rolled broken stone grouted with one part "ATLAS" Portland Cement and two parts clean, fine, sharp sand. The grout was mixed in a Hassam grout mixer. The surface of broken stone after the first grout was placed was covered with a pea grade of broken stone, and this finer stone in turn was covered with a grout of the proportion of one part "ATLAS" Portland Cement and one part sand, and rolled with a steam road roller before the first grout had time to set.

FIG. 21.—HASSAM PAVEMENT, WATERTOWN, MASS.

HASSAM GRANITE BLOCK PAVEMENT.

River Street, in Troy, N. Y., is paved with a Hassam Granite Block Pavement on a Hassam foundation. The foundation in this pavement consists of a 6-inch layer of broken stone grouted with one part "ATLAS" Portland Cement and four parts sand. Grout was mixed in a Hassam grout mixer, was poured upon the broken stone until all voids were filled and the grout flushed

to surface. This foundation was rolled during the process of grouting as well as being thoroughly compacted by rolling before the grout was applied.

The pavement proper consists of granite paving blocks having dimensions 4 to 4½ inches deep, 3½ to 4½ inches wide and 6 to 12 inches long, laid on edge across the street on a sand cushion 1½ inches in thickness placed on the Hassam foundation. Pea stone was sprinkled upon the surface of the blocks and swept into the joints with wire brooms, the pavement rolled to an even surface or rammed when roller could not be used, and the surface was then swept clean and the joints filled with a grout made of one part "ATLAS" Portland Cement and one part clean, sharp sand. The grout was spread upon the paving and brushed into the joints, the stone blocks having previously been wet by sprinkling, and the grout was then broomed to a fine smooth surface. The blocks were laid with joints not to exceed ½ inch.

The sand cost $1.25 per cubic yard delivered upon the street in bags. Crushed stone cost $1.45 per cubic yard delivered. Day labor cost $1.75 per day of 8 hours. Contract price including all materials and labor was $3 per square yard. Fig. 22 shows a cross section of this street.

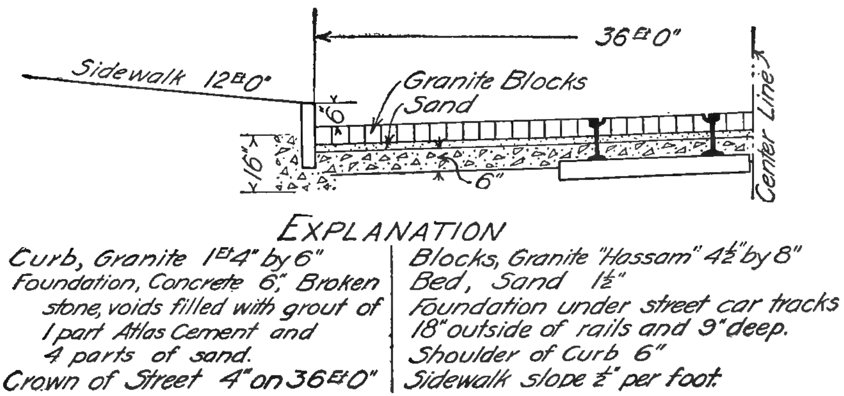


FIG. 22.—CROSS SECTION OF GRANITE BLOCK PAVEMENT ON RIVER STREET, TROY, N. Y.

CONCRETE PAVEMENT IN RICHMOND, IND.

Numerous streets and alleys have been paved with concrete in Richmond as previously stated in this chapter. The first concrete street pavement in Richmond was laid in 1896 at a cost of $1.62 per square yard, since then the cost has been still further reduced.

The usual pavements for streets of ordinary traffic in Richmond have a concrete base 5 or 6 inches thick with a top wearing surface 1 or 1½ inches thick.

For such pavements, that is, those requiring a thickness of 6 or 7 inches, a foundation consisting of 8 inches of rubble, field cobble stone, the refuse from quarries, or coarse gravel is placed. On this layer is spread sufficient gravel to fill the spaces, and, after flooding and ramming, to make a total thickness of the foundation of 10 inches.

On this foundation 5 inches of thoroughly rammed 1:2:5 concrete is laid in blocks 10 feet by 15 feet.

The wearing surface, 1½ inches in thickness, and composed of one part cement and two parts clean, coarse sand; or else of one part cement, one part sand, and one part clean, crushed stone screenings, must be placed on the 5-inch base before the latter has set. This wearing surface is troweled down to insure contact, then leveled off with a straight edge. When hard enough it is floated or troweled to a smooth, continuous surface.

The surface is finally pitted with a brass roller except for marginal strips two inches wide around the edges of the blocks. The wearing surface is cut into blocks the same size as the base.

For streets having heavy traffic a concrete base is laid in addition to the regular pavement so that the total thickness is the same as a brick pavement on a concrete foundation or about eleven inches total. These pavements are constructed as follows:

Where necessary an 8-inch layer of gravel thoroughly wet and consolidated is used for sub-drainage and upon this gravel foundation is placed a 6-inch layer of 1:3:6 Portland cement concrete. When this concrete foundation is strong enough to sustain the roadway pavement it is covered with a coating of fine sand, raked off with a flat board rake so as to remove all sand except that which may remain in low places and voids in the concrete foundation. Upon this sand is placed a thin layer of tar paper and upon the paper a 1:2:5 concrete layer four inches thick.

Upon the above concrete is placed a wearing surface one inch in thickness composed of one part cement, one part clean, sharp sand, and one part clean stone or granite screenings, mixed with water to form a rather wet facing mixture. In some cases this wearing surface is placed in two layers, each one-half inch thick, the first to be thoroughly rammed to insure perfect contact; the second applied immediately after and troweled and worked over, and made to conform to the finished surface of the street. When sufficiently hard, the surface is floated and steel troweled and finished with a cork float.

CONCRETE PAVEMENTS IN THE CITY OF PANAMA.

Fig. 23 shows West Fifteenth Street in the city of Panama being paved with 1:2½:5 "ATLAS" cement concrete five inches thick; after tamping in place it is finished with a straight edge and trowel. The surface is smooth but

not slippery. The concrete, hand mixed, was placed with wheelbarrows. Broken stone was obtained by crushing old cobble stones. The sand was obtained from Panama Beach. In 1906 and 1907 over two miles of this pavement was laid in the city of Panama at a cost of $2 per square yard on streets having grades as high as 8 per cent. It was laid in alternate blocks or sections about 10 feet long lengthwise of the street and extending all of the way or one-half way across the street between curbs. The streets vary in width from 13 feet to 20 feet between curb lines.

FIG. 23.—CONCRETE PAVEMENT IN THE CITY OF PANAMA.

GROUTING STONE BLOCK AND BRICK PAVEMENTS.

For filling the joints in stone block or brick pavements the cement grout should be mixed one part "ATLAS" Portland Cement and one part clean sand with enough water to make the grout flow easily. The materials must be thoroughly mixed with hoes in a tight box at the place of using. As soon as the mixing is completed the grout must be immediately poured out of the box upon the surface of the pavement and broomed into the joints before the cement sets.

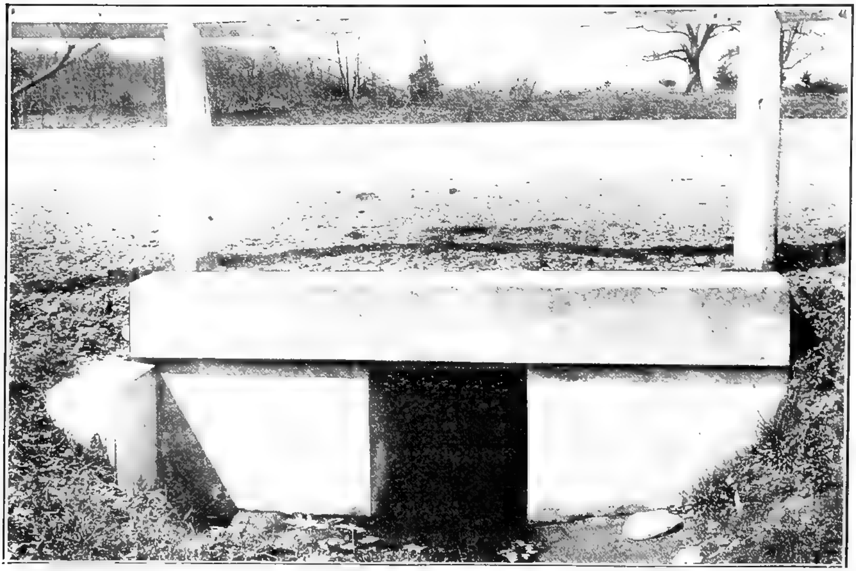
Every twenty-five feet, measured lengthwise of the street, one or two transverse joints should be filled with tar to provide for expansion. The joint next to each curb should also be filled with tar.

CHAPTER IV.

SEWERS, DRAIN TILES, BROOK LININGS, CONDUITS.

SEWERS.

While formerly all large sewers were built of brick and the smaller ones of vitrified clay or cast-iron pipe, in recent years concrete has entered this field of construction and through a process of expansion and adaptation has been



BOX CULVERT, AMHERST, MASS.

gradually supplanting all of these materials. At first its use was limited to foundations and the lower part of side walls, then to lining the inverts of brick sewers, and finally increasing experience and additional confidence has led to its use for the construction of entire concrete sewers and also sewer pipes.

The larger concrete sewers, molded in place, are practically monolithic, while the smaller ones, constructed by joining short lengths of concrete pipes together and sealing the joints, make one continuous pipe.

Aside from being generally cheaper than brick, concrete sewers are more permanent and water-tight, have a much smoother surface and therefore a greater carrying capacity, and are less liable to damage and collapse through excessive loads, vibrations and unsuitable foundations.

CONCRETE PIPE SEWERS.

While monolithic sewers molded in place are entirely satisfactory for diameters of more than 30 inches, owing to the difficulty of devising suitable forms they are impractical and less economical for smaller diameters. Concrete pipe, on the other hand, can be made economically and easily in sizes ranging from 3 inches to 36 inches inside diameter.

Concrete pipes can be made wherever gravel, sand and cement can be brought together, and at a cost considerably lower than cast-iron pipe and usually less than vitrified clay. They can be molded as desired into sectional forms which are more conducive to stability and efficiency than the circular cross-section which is necessary with cast iron or vitrified clay. By giving concrete pipe a broad, flat level base, they are made to rest firmly and securely on a continuous, flat earth foundation, while to secure such a bearing for a circular pipe requires tamping the earth filling into the space beneath the two sides of the pipe and also cutting out a depression in which the bells can rest.

In localities where there are great variations in the amount of sewage flowing through the pipes an oval form of cross section is better than a circular one. For this concrete must be used, since vitrified pipe cannot be made into these forms on account of the warping due to burning.

This warping also prevents the finished section of vitrified pipe from being truly circular so that when these pipes are fitted together there are rough projections at many points on the inside of the pipe which tend to collect solid matter in the sewage and thus to reduce its carrying capacity.

Concrete pipes can be given a tapering butt joint, instead of the bell and spigot joint common for vitrified and cast-iron pipe, which considerably re-

TESTS OF PLAIN CONCRETE SEWER PIPE IN BROOKLYN.*

Kind	Diameter, Inches	Thickness, Inches	Age	Breaking Load, Lb. per Lin. Ft.
A	12	1 3/16	32 days	1,689
B	15	1 7/16	33 days	1,800
B	18	1 3/8	29 days	1,767
A	12	1 3/16	1 month 29 days	1,622
B	15	1 1/2	2 months 3 days	1,617
B	18	1 7/16	1 month 29 days	1,522
C	6	1 5/16		2,600
A	9	1 3/16	Several years over 3 years	2,011
A	12	1 1/4	2 years 9 days	1,983
B	15	1 1/2	1 year 7 months 20 days	1,962
B	18	1 5/8	2 years 7 days	2,022
B	24	2 1/8	2 years 1 month 28 days	1,978

A, circular pipe with flat base. B, egg-shape with flat base. C, circular pipe.

*Part of table from Engineering Record, Vol. 58, Nov. 21, 1908, p. 591.

duces both the cost of manufacture and of joining the pipe with mortar in the trench.

That concrete pipes without reinforcement possess sufficient strength for use as sewers is shown in the accompanying table* which gives the results of tests on pipes made in the testing laboratory of the Bureau of Sewers of Brooklyn, N. Y.

The pipes which, as seen from the accompanying table, varied in diameter from 6 to 24 inches, were made of a mixture of 1½ parts cement to 1 part sand to 3 parts trap rock screenings, and were tested at ages varying from twenty-nine days to over two years. The 6-inch pipes were made 24 inches long while the larger diameters were 36 inches in length. They were tamped into molds, and then subjected to heat to dry them immediately after molding,

CULVERT, DUMONT, N. J.

the forms being removed within half an hour after the work on a length was started.

In testing a section of the pipe it was laid on a sand bed so that the lower one-sixth of its circumference was in contact with the sand and then the pressure was applied from the testing machine along the upper surface of the pipe until the pipe broke. In order to secure an even distribution of the pressure along the length of the pipe, the pressure was applied through a strip of plaster of Paris one inch wide and not over one-quarter inch thick, held in place by strips of wood.

The accompanying table shows the sizes of the pipe in inches together with the thickness of the walls, the age, and the breaking load in pounds per linear foot. In order to break a 12-inch pipe 32 days old, for example, a load of 1,689 pounds on each foot of length of the pipe was required, the total load for the 3 feet of pipe being thus three times 1,689, or 5,067 pounds.

The pipes, it must be remembered, were of plain concrete without reinforcement.

LARGE CONCRETE SEWERS.

Large sewers and conduits are built of plain concrete and also of reinforced concrete. For diameters of 3 to 4 feet the thickness required for good construction is usually sufficient without reinforcement as they can be reckoned as strong as a brick sewer of the same diameter which is half again as thick. For large diameter, reinforcement is generally advisable, and the saving in material will more than counterbalance the added cost of reinforcing. The reinforcement adds to the strength of the sewer during construction, and when completed enables it to withstand a larger pressure after the earth is filled in around and on top of the pipe, and also renders it less liable to damage where there is danger of settlement.

THICKNESS OF CONDUITS*

Diameter of Conduit	Thickness of Crown, Inches	Thickness of Haunch, Inches	Thickness of Invert, Inches
2	4	6	5
6	7	18	8
12	13	23	14

"If reinforcement is used, the thickness for conduits for ordinary sizes is usually determined by the minimum thickness of concrete which can be laid so as to properly imbed the metal. This minimum for the large diameters where steel is advisable may be taken as 6 inches."

As a guide for determining the thickness of concrete required for both plain and reinforced concrete sewers, the general rule used by Mr. William B. Fuller* is given as follows:

"If concrete is not reinforced and ground is good—able to stand without sheeting—make crown thickness a minimum of 4 inches, and then one inch thicker than diameter of sewer in feet. Make thickness of invert same as crown plus one inch except never less than 5 inches.. Make thickness at haunches two and a half times thickness of crown, but never less than 6 inches.. If ground is soft or trench is unusually deep, these thicknesses must be increased according to experienced judgment."

SIZES OF CIRCULAR CONCRETE SEWER PIPE.

Fig. 24 shows one form of concrete circular pipes suitable for sewer con-

*See reference, footnote, page 18.

struction. The pipes are shown 2 feet 6 inches in length over all, the inside diameters can be anything from 12 to 48 inches, and the thickness of the pipe from 2 to 6 inches. The joints are beveled so that when laid with Portland cement mortar the joints will be practically water tight, and will present a smooth surface so that solid matter will not be deposited, as is apt to be the case in vitrified pipe sewers.

In laying these pipes a little mortar mixed 1 part "ATLAS" Portland cement and 2 parts clean sharp sand is placed inside of the pipe in the inner beveled surface. The pipe is then pushed hard against the beveled end of the length of pipe already laid, and the mortar smoothed off inside and outside of the pipe so as to make a smooth joint.

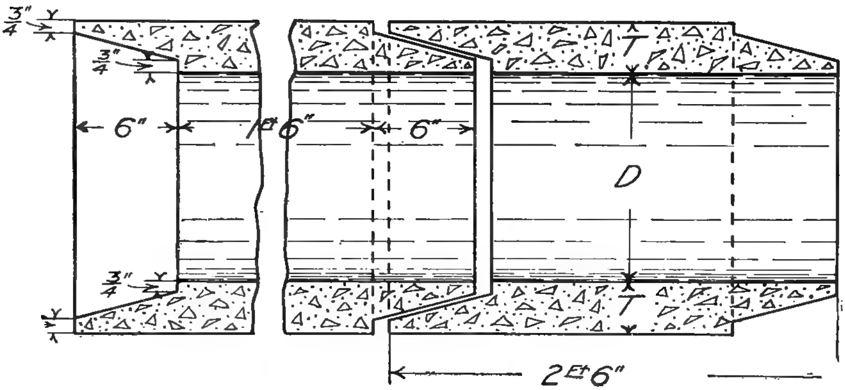


FIG. 24.—LONGITUDINAL SECTION OF SEWER PIPES.

The inside diameter of the pipes, D in Fig. 24, are 12, 18, 24, 30, 36, 42, and 48 inches, and the thickness T in the figure corresponding to these diameters should be 2, 3, 4¼, 4½, 4¾, 5¾, and 6 inches. That is, for a 12-inch pipe the thickness should be 2 inches; for an 18-inch pipe, 3 inches, and so on. For drain tile, which need not be so thick as sewer pipe, thinner pipe may be used.

PROPORTIONS OF CONCRETE FOR SEWER PIPE.

Concrete used in the construction of sewer pipe, that is, in the construction of pipes having diameters of 12 or more inches, should be mixed in the proportions of 1 part "ATLAS" Portland Cement, 2 parts clean, sharp sand, to 4 parts crushed stone or clean coarse gravel not more than 1 inch in diameter.

CONCRETE DRAIN TILE.*

Tiles are used for draining roadways and farms.* A roadway of even the best material needs some drainage and for roadways made of poor materials drainage is absolutely essential. Concrete drain tiles are the best for the under drainage of any roadway or sidewalk. Oftentimes in the construction of roads and sidewalks one or more longitudinal lines of drain pipes are laid underneath the surface of the road or sidewalk and at convenient places are carried to proper outlets. Frequently a drain 4 inches in diameter is sufficient for draining sidewalks or roadways.

SIZE OF CONCRETE DRAIN TILES.

Concrete drain tiles are made in sizes of 4 inches to 30 inches inside diameter. Ordinarily the sizes from 4 to 12 inches are molded by machine, although they may be made in simply constructed molds as described in "Concrete Construction about the Home and on the Farm," while the larger sizes are usually made by hand. Although concrete sewer pipes have either bell shaped or other similar joints, concrete drain tiles are nearly always made with plain ends.

The thickness of the shell for tiles varies from 1 inch or even thinner for the 4-inch pipes to 3 inches for the 36-inch pipes. The sizes under 10 inches in diameter are made 1 inch or less in thickness; the 12 to 24-inch, from 1 to 2 inches thick; the 24 to 36-inch, 3 inches.

Usually sizes under 10 inches in diameter are made 18 inches long and those 10 inches or more are made 2 feet long.

MIXTURES FOR TILES.

The best mixture for tiles is 1 part "ATLAS" Portland Cement to 3 parts clean coarse sand, or sand and gravel passing a ½-inch screen.

A 1:3 mixture for drain tiles to be used in roads, either for longitudinal or cross drains, gives the proper strength to the pipes. For farm drainage and other similar locations where there is not much pressure exerted upon the pipe a 1:4 mixture is sometimes used.

CURING.

For ordinary drain tiles the concrete should be mixed with enough water so that the moisture will show at the surface when the concrete is tamped. As a general thing, the molds can be removed as soon as the concrete is thor-

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*See also "Concrete Construction about the Home and on the Farm," p. 91. This book may be obtained by writing to The Atlas Portland Cement Co., New York.

oughly rammed into them. After the molds are removed, the tiles should be placed in the shade, and wet down as soon as the concrete will stand the water without washing, which is ordinarily from 8 to 10 hours after molding. It is of the utmost importance that they should not be allowed to dry out for at least 4 days, and they should also be kept in the shade for 8 or 10 days, being wet once or twice each day during this period. If the weather is very dry or hot, 3 or 4 wettings for the first few days are desirable. A pretty good rule to follow is that the pipes must not be allowed to dry "white" until they are at least 8 days old. After this treatment the tiles should be stored in an open

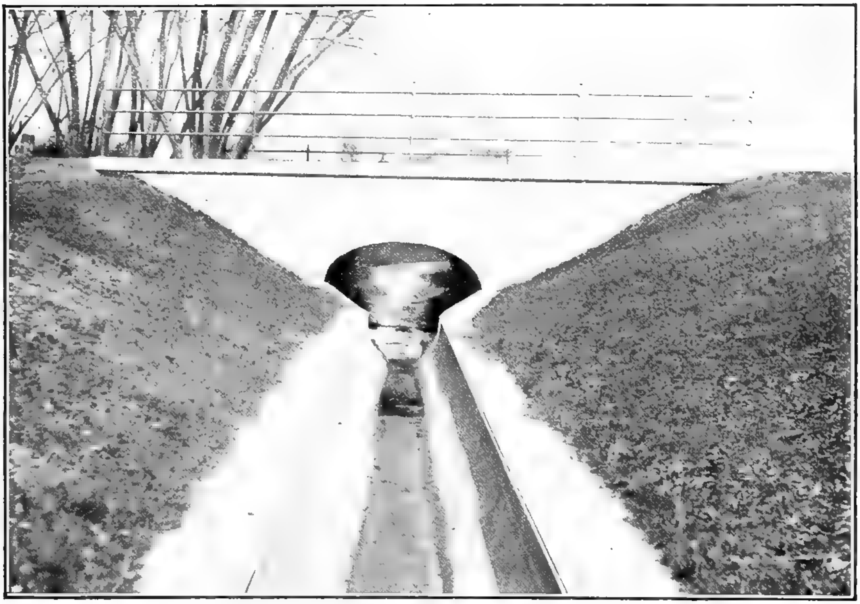


FIG. 25.—CONCRETE BROOK LINING IN NEWTON, MASS.

yard to season and harden. In ordinary weather the pipes are ready for shipment in 30 days.

LAYING DRAIN TILES.

Concrete drain tiles under roads must have at least 1 foot of earth on the top of the pipe and they must be laid on a grade of at least 1 foot in 100 feet, that is, one foot fall of the pipe in 100 feet of distance.

The pipes should be laid with open joints, that is, with the ends simply abutting without any mortar.

BROOK LININGS.

A small stream of water running through a town or through the flats adjoining a town often is the cause of a great deal of trouble. If the adjoining lands are to be divided into house lots the brook must be properly taken care of. Usually the best solution for this problem is to change the course of the brook so that it will flow under a street through a concrete conduit. If the stream is not within the limits of a street the banks can be lined with

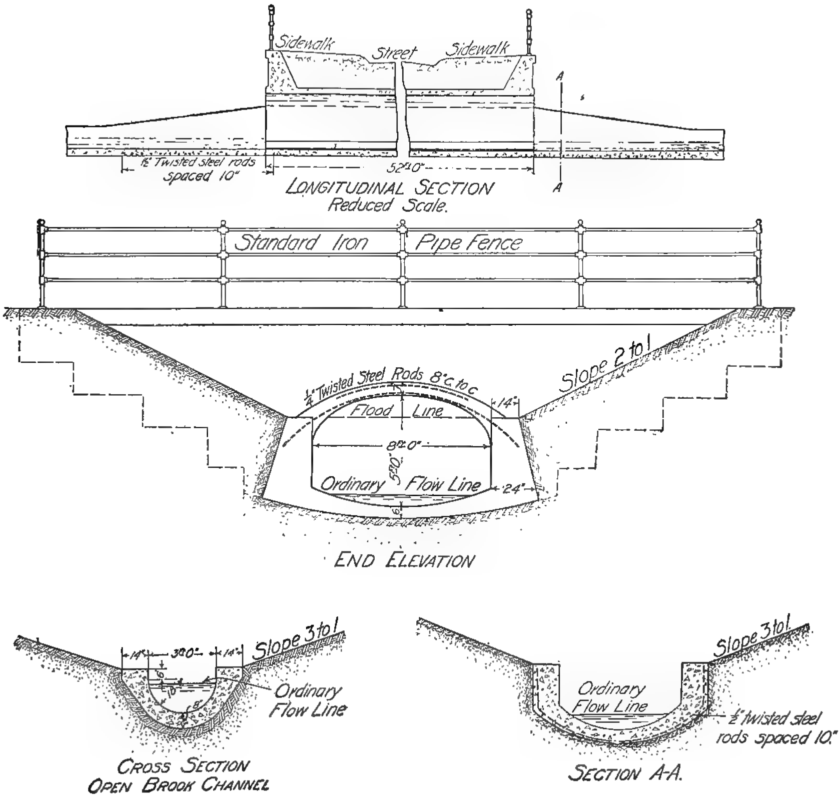


FIG. 26.—CONCRETE BROOK LINING IN NEWTON, MASS.

concrete, the top thus being left open. The concrete lining prevents the nuisance caused by the breeding of mosquitoes and other insects along the edges of the open brook. Fig. 26 shows typical drawings of a brook lining in Newton, Massachusetts. The concrete lining, throughout most of the length is curved to a radius of 18 inches, inside diameter, and for the most part is 8 inches in thickness, the invert being 8 inches and the thickness at the upper

surface of the concrete being 14 inches. Under the ordinary flow the concrete channel does not run full. During extreme high water the cross section of the channel is not sufficient to carry the entire flow so that once in a great while the water overflows the normal cross section.

Fig. 26 shows, in addition to the normal cross section of the channel, the sections where it enlarges to pass under a small culvert which carries a street over the brook. At section A-A the concrete is reinforced with half-inch rods spaced 10 inches apart. The culvert itself has a clear span of 8 feet and a total depth of 5 feet. The thickness of the invert of the culvert is 6 inches at the middle, gradually enlarging towards the abutments while the arch is 7 inches thick at the crown and increases gradually towards the abutments and is reinforced with ¼-inch steel rods 8 inches apart on centers.

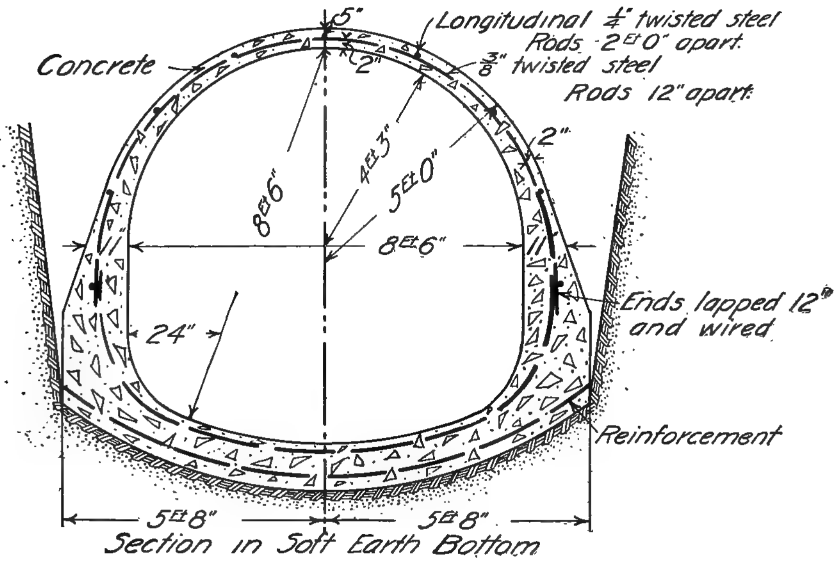


FIG. 27.—TYPICAL CROSS SECTION, JERSEY CITY CONDUIT.

Fig. 25 is an illustration of the brook shown in detail in Fig. 26. The photograph was taken at a very low stage of the water.

For brook linings the concrete should be mixed 1 part "ATLAS" Portland Cement, 2½ parts sand and 5 parts broken stone or screened gravel. Concrete linings should be laid in sections not over 20 feet in length, and the end of one section should be built into the adjacent section in a tongued and grooved manner.

Sometimes these concrete brook linings are connected with nearby sewers

so that the sewers are automatically or continuously flushed by some water passing from the brook into the sewer.

CONDUITS.

Oftentimes a covered conduit is necessary to carry the water of a brook located under a street surface. Such conduits may be made rectangular or circular in cross section. They are also frequently used for water supply lines where there is little or no pressure within the concrete conduit.

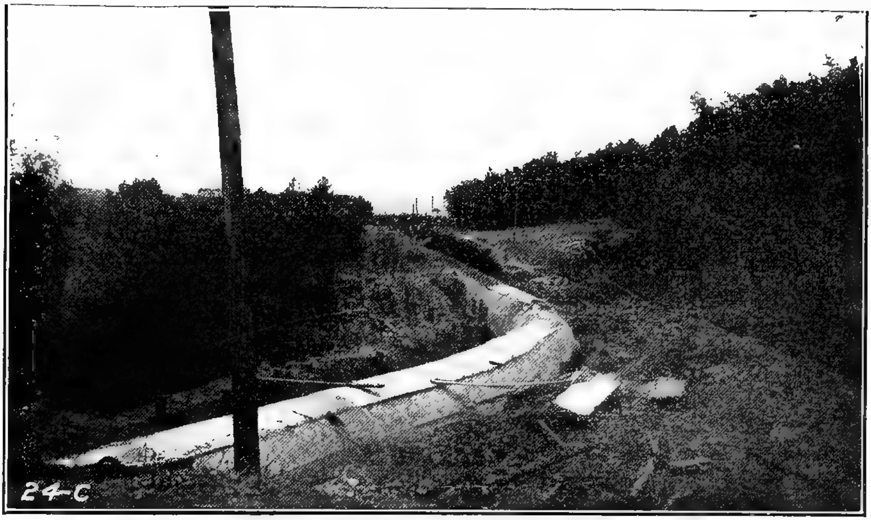


FIG. 28—JERSEY CITY CONDUIT.

Fig. 27 shows a typical cross section and Fig. 28 a photograph of a concrete conduit of the Jersey City Water Supply Company built to carry a water supply. This conduit is approximately 8 feet 6 inches inside diameter and for a length of about 20,000 feet is made of concrete. About 30,000 barrels of "ATLAS" Portland Cement were used in this conduit.

The thickness of the conduit at the crown varies from 5 to 8 inches depending on the kind of material in which the pipe is placed and the depth of the filling over the pipe. The section shown in Fig. 27 is typical of those used in soft earth.

For sections laid in open trench the concrete was mixed 1 part "ATLAS" Portland Cement and 7 parts sand and ballast. The ballast was broken trap rock, the run of the crusher being used. All concrete was machine mixed and was very wet.

CHAPTER V.

CULVERTS.

Concrete is an excellent material for the construction of culverts as is shown by the great number of concrete culverts now being built for highways and railways. As the entire culvert is made of concrete there is nothing to decay and the excessive maintenance charges in timber construction are entirely lacking.

Culverts vary greatly in size and shape. The best way to determine the

BEAM BRIDGE NEAR PARIS, MO.

required size for an opening so that the waterway will be sufficient is to measure the width and depth of the stream at some narrow point near by during the high water stage, and if possible compare this size with that of culverts over the same stream in the neighborhood. With this information the width and depth of the culvert opening may be chosen.

Culverts may be either square, rectangular, circular, or arched in cross section. Generally the rectangular section is best because it conforms more nearly to the cross section of the water way and is cheaply and easily built. Where the appearance is of more importance than the cost, arch culverts are preferable to other styles. Whatever the form of cross section the construc-

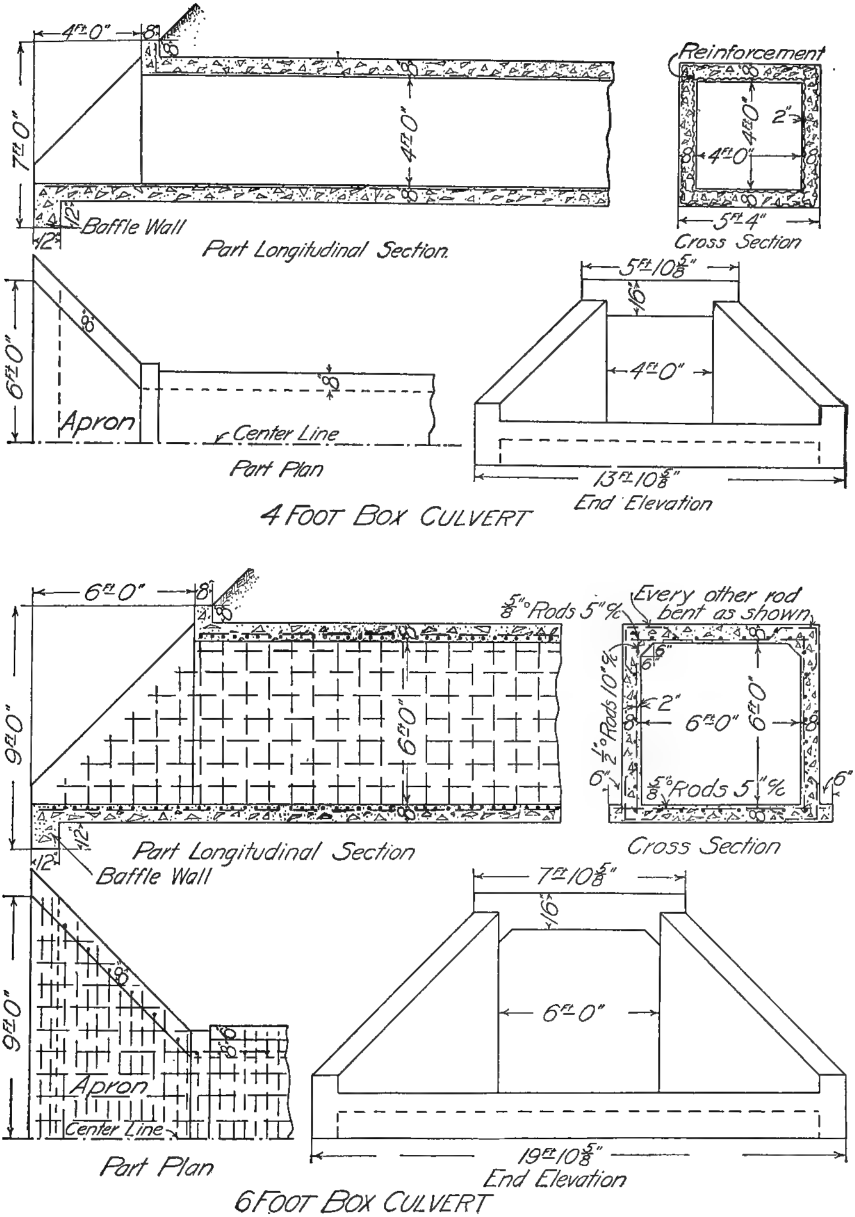


FIG. 29.—REINFORCED CONCRETE BOX CULVERTS.

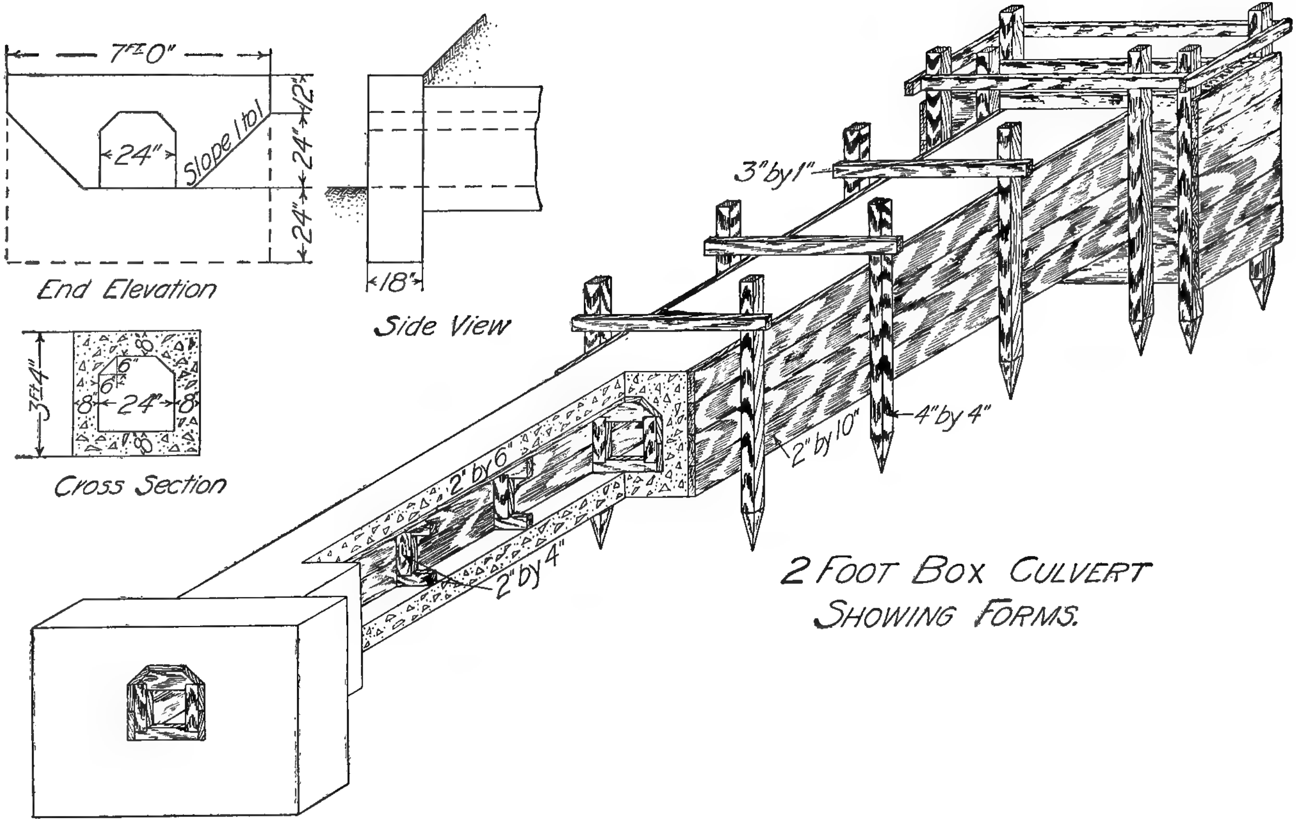
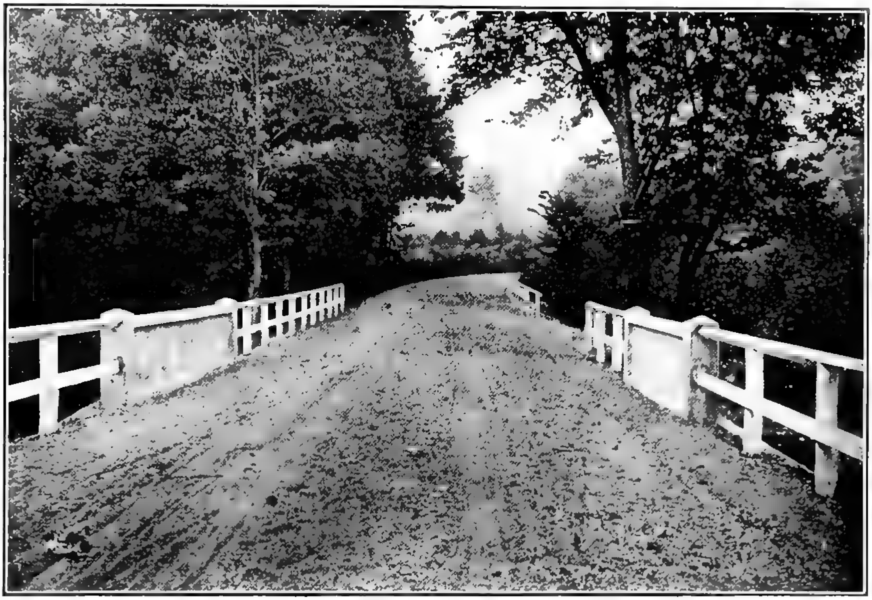


FIG. 30.—SMALL CONCRETE BOX CULVERT WITH FORMS.

tion should be such as to prevent undermining, that is, to prevent the water from running along the outside of the culvert and thus washing out the earth embankment.

Culverts with square or rectangular openings are called box culverts, and those with circular sections are called pipe or circular culverts. Pipe culverts are made entirely of concrete or else of tile or iron pipe with a concrete head wall at each end of the pipe where it projects from the sides of the road.



BEAM BRIDGE.

Concrete for culverts should be made one part "ATLAS" Portland Cement, two and a half parts sand, and five parts broken stone.

BOX CULVERTS.

Box culverts may have square or rectangular sections as in Fig. 29 or Fig. 32 or a section similar to that shown in Fig. 30. For small culverts, the last is a neat design, having an arch effect and yet being cheaply and easily constructed. The cost of the small box culvert shown in Fig. 30 may be slightly reduced if the cross section is made square, omitting the bevels at the upper corners.

Fig. 29 shows a good design for a 4-foot box culvert of ample strength to carry a highway.. To prevent undermining, a concrete invert or bottom is used and a baffle wall and apron at each end should be constructed as shown

although some culverts where the soil is hard do not need the apron, baffle wall or bottom. Cobble stones or paving bricks may be used instead of concrete for covering the bottom between the side walls. They may be laid even in running water and in case a dry season should occur the spaces between the stones or bricks may be filled with cement grout.. Concrete must not be laid in running water for the cement will be washed out from the aggregate. This 4-foot box culvert has top, bottom and sides 8 inches in thickness and is reinforced with expanded metal No. 10 gage having 3-inch meshes, or with other similar reinforcement placed not less than 1½ and not more than 2 inches from the inner surface of the culvert. The sheet reinforcement should also be placed in the apron and in the wing walls.

The lower part of Fig. 29 shows a design for a box culvert with opening 6 by 6 feet similar to the 4-foot box culvert above described except that round steel rods are used instead of sheet reinforcement. In the bottom of the culvert proper the rods running at right angles to the length of the culvert should be ⅝ inch in diameter and spaced 5 inches apart. For the top they should be ⅝ inch in diameter, spaced 5 inches apart and alternate rods should be bent, as shown in Fig. 29, to reinforce the side walls extending within three inches of the bottom surface of the concrete. This bending of the alternate rods in the top results in the vertical rods of the sides being spaced 10 inches apart. In the apron the ⅝-inch rods should be spaced 5 inches apart and should be bent up alternately so that the vertical rods in the wing walls are spaced 10 inches.

In addition to the rods above mentioned there should be a set of ½-inch diameter rods running parallel to the length of the culvert spaced 10 inches apart which should extend into the apron and wing walls at each end.

Fig. 31 and Fig. 32 show a reinforced box culvert built in Lenox, Massachusetts, in 1896, for the Massachusetts Highway Commission. The body of the culvert is reinforced with ⅞-inch square twisted steel rods 8 inches c. to c. at each corner where the side walls meet the top and bottom, those at the bottom corners being 24 inches long and bent, while those at the top corners are straight and 14 inches in length. Four counterforts for bracing the side walls are shown in the plan and also in section C1C, Fig. 32, are used in this culvert.

Forty cubic yards of broken stone, 16 cubic yards of sand, 55 barrels of cement, and 778 pounds of steel were used.. One hundred twenty-one cubic yards of earth were excavated. The concrete mixture was about one part "ATLAS" Portland Cement, two and one-half parts sand, and five parts crushed stone, and the 44 cubic yards in the structure cost $660, or $15 per cubic yard. The earth excavation cost 75 cents per cubic yard. The total cost of the culvert to the Commission, exclusive of the macadam roadway was

$809.67. The cement cost the contractor $1.85 per barrel, plus 50 cents for hauling, making the price at the culvert $2.35 per barrel. The contractor paid $2 per load of about 1 cubic yard for the sand delivered at the culvert and about $1.15 per cubic yard for the stone. About 3½ or 4 days were required for excavating and the concreting extended over 24 days including delays.

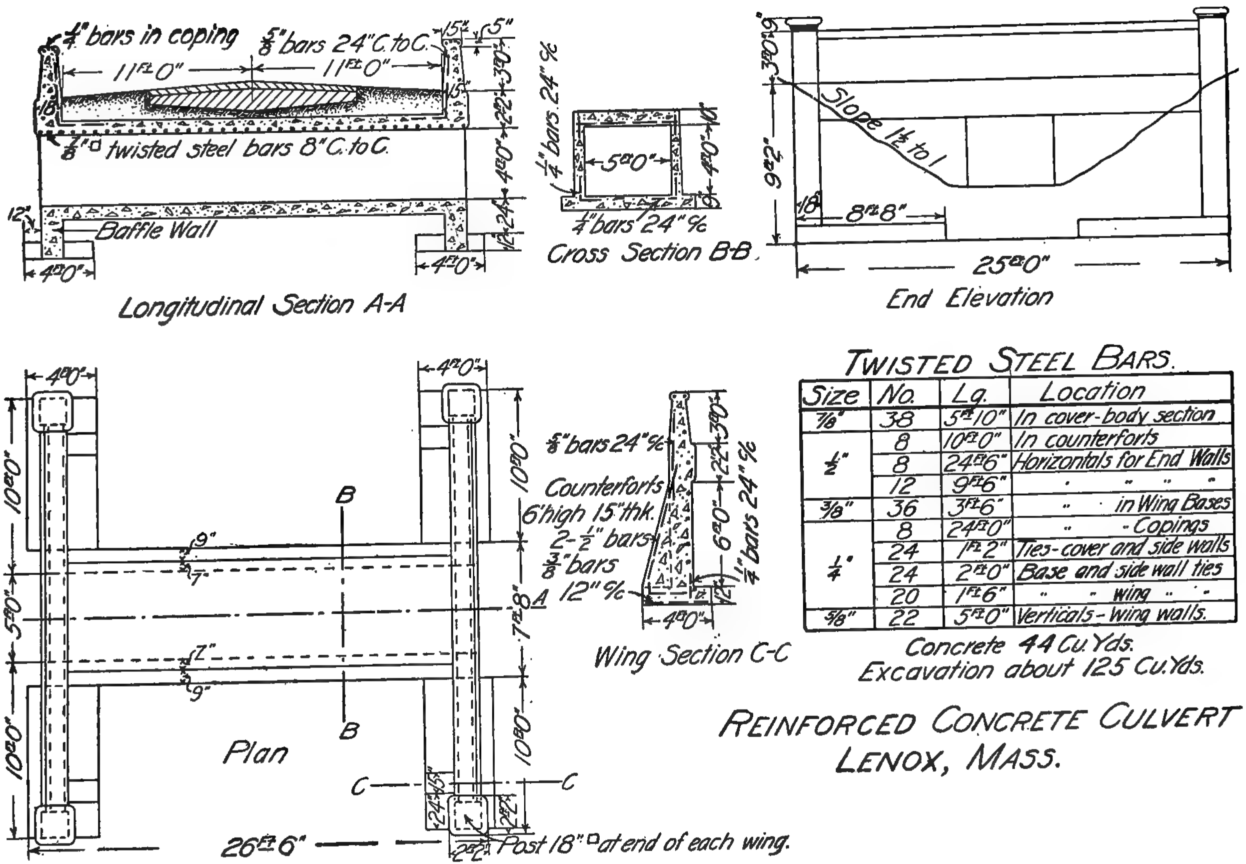
A small box culvert with an opening 2 by 2 feet is shown in Fig. 30 in which the head wall, culvert proper, and arrangement of forms are all clearly illustrated. If the soil is compact material like hard clay, where the excavation can be made to the exact size and shape of the culvert, the outer forms may be omitted, the concrete being deposited directly on the bottom of the

FIG. 31.—REINFORCED CONCRETE BOX CULVERT AT LENOX, MASSACHUSETTS.

trench to form the invert of the culvert, then the inner form set in place and the concrete deposited between it and the walls of the trench.

The inner forms consist of frames made of three pieces of 2 by 4 inch and one piece of 2 by 6-inch joists, notched as shown. Around these frames boards are set. The upper 2 by 6 piece is not nailed so that in removing the inner forms after the concrete has hardened this upper piece is first knocked out and then the 2 by 4-inch pieces and finally the boards.

Another type of small culvert and form as used by the Iowa State Highway Commission is shown in Fig. 33.



TWISTED STEEL BARS.

Size	No.	Lg.	Location
7/8"	38	5 Ft. 10"	In cover-body section
1/2"	8	10 Ft. 0"	In counterforts
	8	24 Ft. 6"	Horizontals for End Walls
	12	9 Ft. 6"	" " "
3/8"	36	3 Ft. 6"	" in Wing Bases
1/4"	8	24 Ft. 0"	" Copings
	24	1 Ft. 2"	Ties-cover and side walls
	24	2 Ft. 0"	Base and side wall ties
	20	1 Ft. 6"	" " wing "
5/8"	22	5 Ft. 0"	Verticals-Wing walls.

FIG. 32.—REINFORCED CONCRETE BOX CULVERT AT LENOX, MASSACHUSETTS.

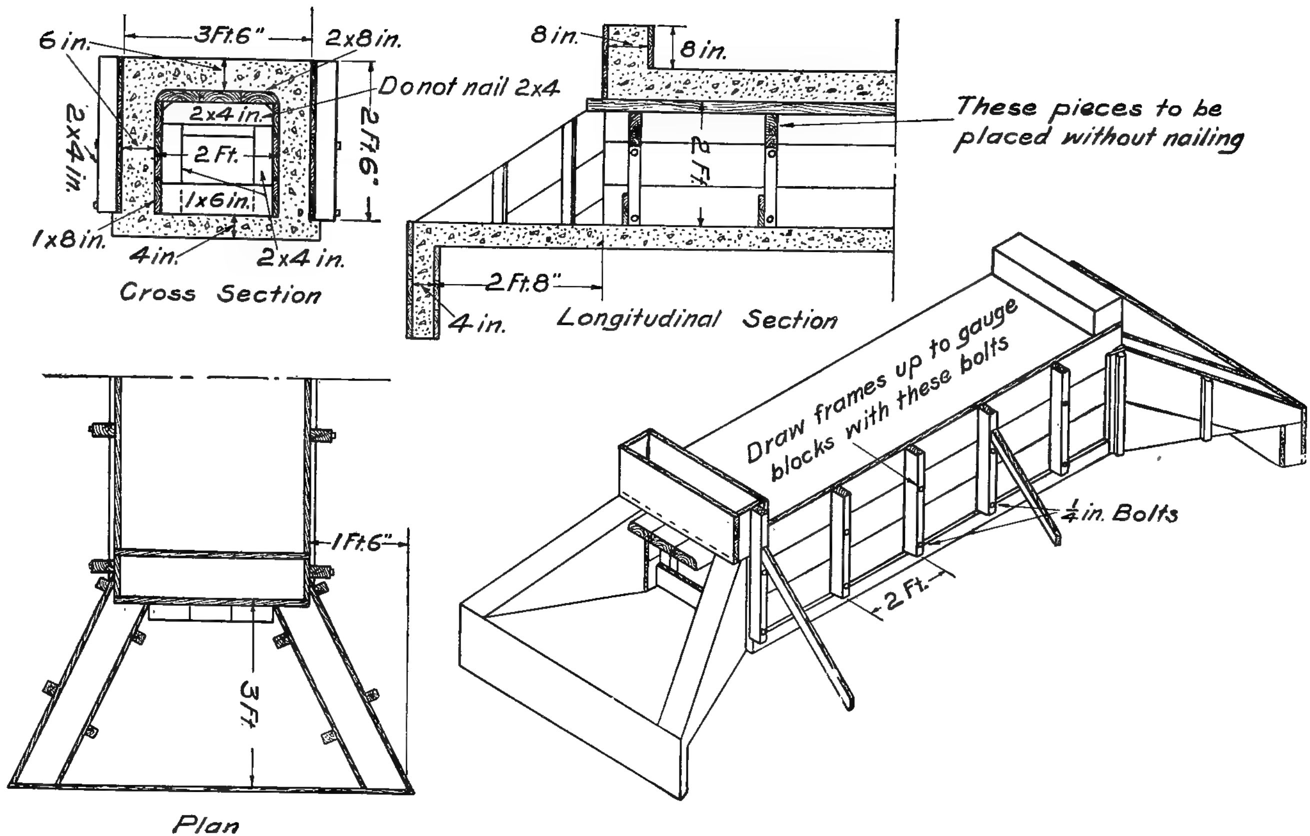


FIG. 33.—SMALL BOX CULVERT AND FORMS, IOWA STATE HIGHWAY COMMISSION.

CIRCULAR OR PIPE CULVERTS.

Circular or pipe culverts are made of concrete as in Fig. 34, or of metal with concrete head walls as in Fig. 35. The concrete culvert shown is 3 feet in diameter and is not reinforced. An apron with a baffle wall on each side as well as on the outer end is provided to prevent the water from running along the outside of the culvert and thus washing out the earth.

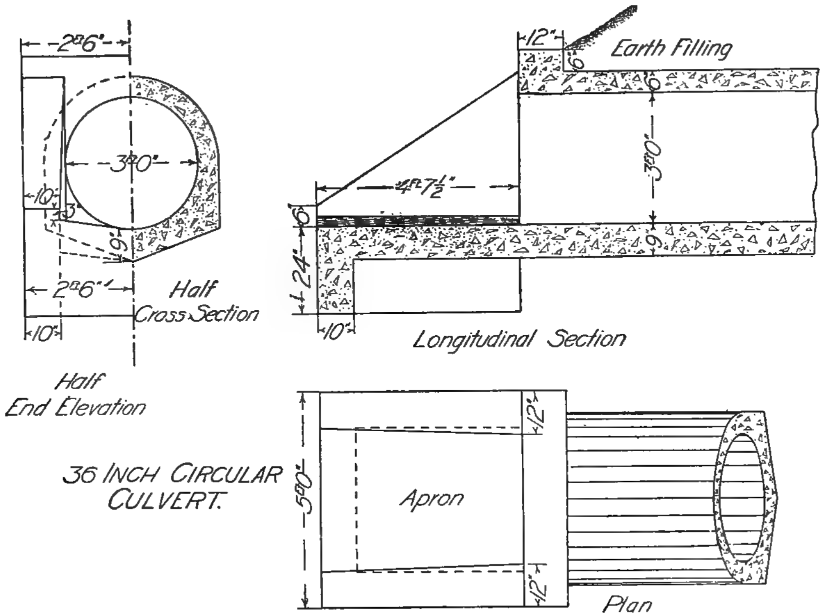


FIG. 34.—CONCRETE CIRCULAR CULVERT.

Pipe culverts are made of cast iron or sheet iron or of tiles. They should have fall enough so that water will not stand in them, a slope of ¼ inch per foot being generally sufficient. They should also have at least 12 to 18 inches of earth over the top of the pipe and the earth should be thoroughly compacted around the outside of the pipe.

To prevent undermining, head walls should always be used with pipe culverts. In Fig. 35 head walls for four sizes of metal pipes are shown and they are all similar except that for the 24-inch pipe the head wall has a coping 6 inches deep projecting 2 inches from the face of the wall, and the head wall for the 3-foot pipe has a concrete apron 6 by 24 by 48 inches in size. This apron should slope up at the inlet and down at the outlet.

The number of cubic yards of concrete in one head wall for the 12, 18, 24, and 36-inch pipe is 0.64, 1.04, 1.47, 2.57 respectively. The 2.57 cubic yards in the headwall for the 36-inch pipe includes the concrete in one apron.

If the proportions are one part "ATLAS" Portland Cement, two and one-half parts sand and five parts broken stone or screened gravel, 1 1/3 bbls. cement (each barrel being the same as four bags) will be required for a cubic yard together with about ½ cubic yard of sand and a cubic yard of broken stone or screened gravel.

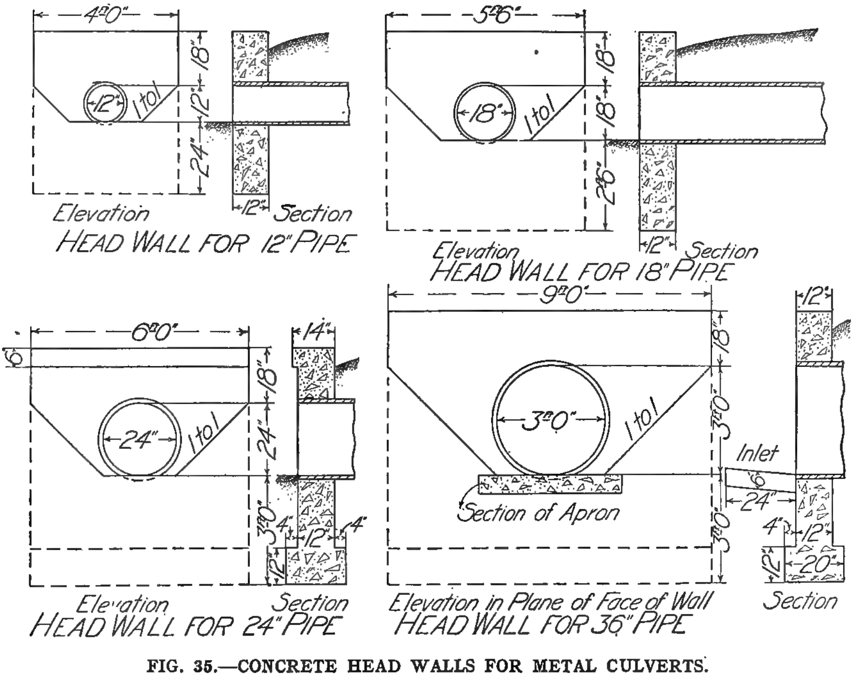


FIG. 35.—CONCRETE HEAD WALLS FOR METAL CULVERTS.

ARCH CULVERTS.

As previously stated, arch culverts are more expensive and more difficult to build than box culverts, but nevertheless they are frequently used where an artistic design is desirable. The culvert of 5-foot span, illustrated in Fig. 36, is very similar to the design for the 5-foot span shown in Fig. 39, and was built in Bureau County, Illinois, by the Illinois Gravel Company of Princeton, Illinois. It contains 11.4 cubic yards of concrete mixed one part "ATLAS" Portland Cement to six parts sand and gravel, using gravel as the large aggregate with coarse sand to fill the voids. The cost of the cement delivered

at the bridge was $1.35 per barrel. Actual cost of the culvert was $75.00, which included long haul charges for gravel.

Figs. 37, 38 and 39 show designs for arch culverts of 5, 8, and 10-foot clear spans respectively, suitable for highway construction where the soil is firm, as compact sand or hard clay. If the soil is soft clay or loam, the footings should be made wider so as to give a larger bearing area for the walls as well

FIG. 36.—CONCRETE ARCH CULVERT IN BUREAU COUNTY, ILLINOIS.

as for the arch proper. Of course, if the soil is too soft, box instead of arch culverts should preferably be used, or else the bearing power of the soil should be increased as indicated below under "Preparing the Bed."

As shown in Fig. 38, each end wall of the 10-foot span should be reinforced with 14 long vertical rods and with 8 short bent rods, the latter extending horizontally two feet into the arch and vertically two feet into the end walls; and in addition there should be 4 long horizontal rods in each end wall. All rods are ½ inch in diameter. The 5-foot span has no reinforcement except 5 bent rods to tie each end wall to the arch.

The designs show a width of 10 feet between the walls, but this can be increased to any distance desired.

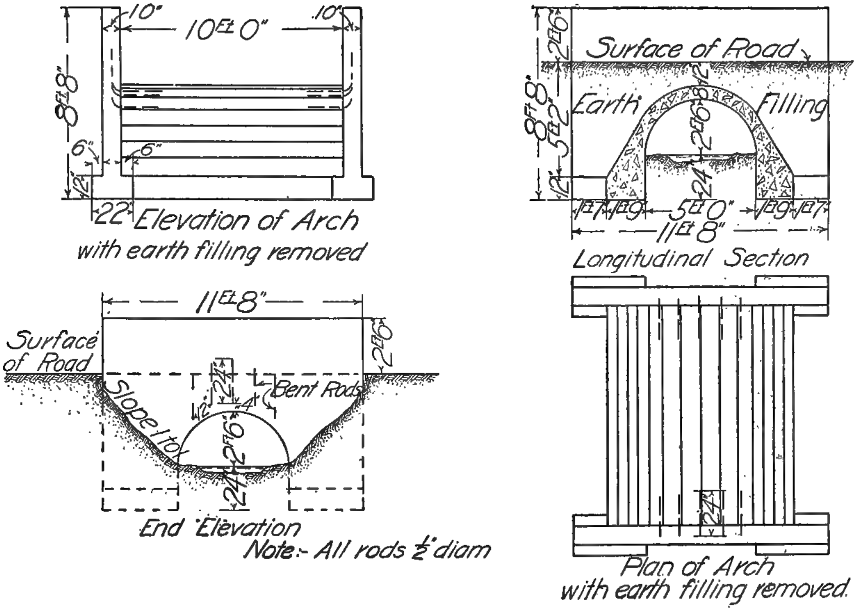


FIG. 37.—ARCH CULVERT FOR FIVE-FOOT SPAN.

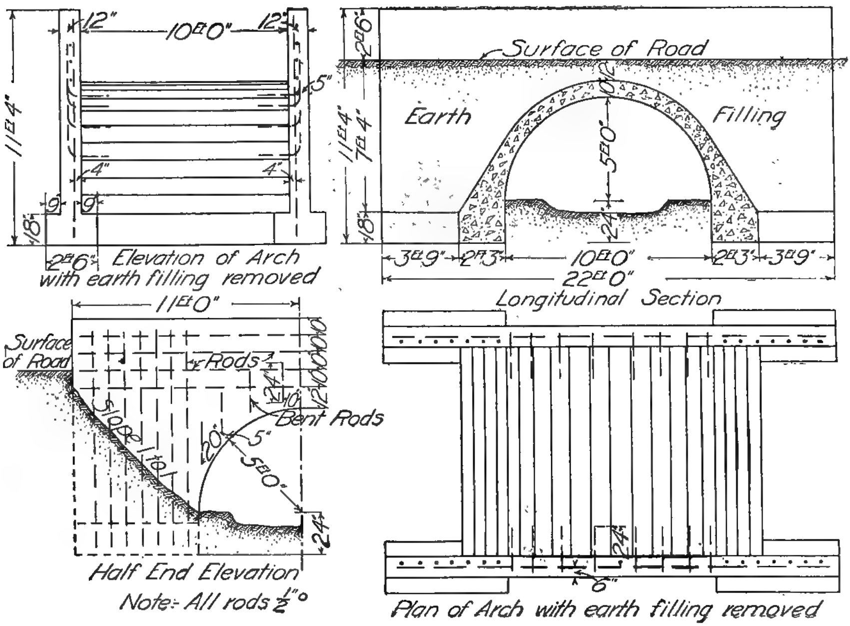


FIG. 38.—ARCH CULVERT FOR TEN-FOOT SPAN.

ARCH IN BUREAU CO., ILLINOIS

BEAM BRIDGE, GROTON, MASS.

In the 5-foot span there are 4.25 cubic yards in each end wall and 4.73 cubic yards in the arch between the end walls, making a total of 13.23 cubic yards of concrete in the structure. In case the roadway is wider than here assumed, the total number of cubic yards of concrete in the structure may be computed by adding to 8.5 the product of 0.473 times the distance in feet between the end walls; 8.5 being the cubic yards of concrete in the two walls and 0.473 the number of cubic yards of concrete in one foot length of arch.

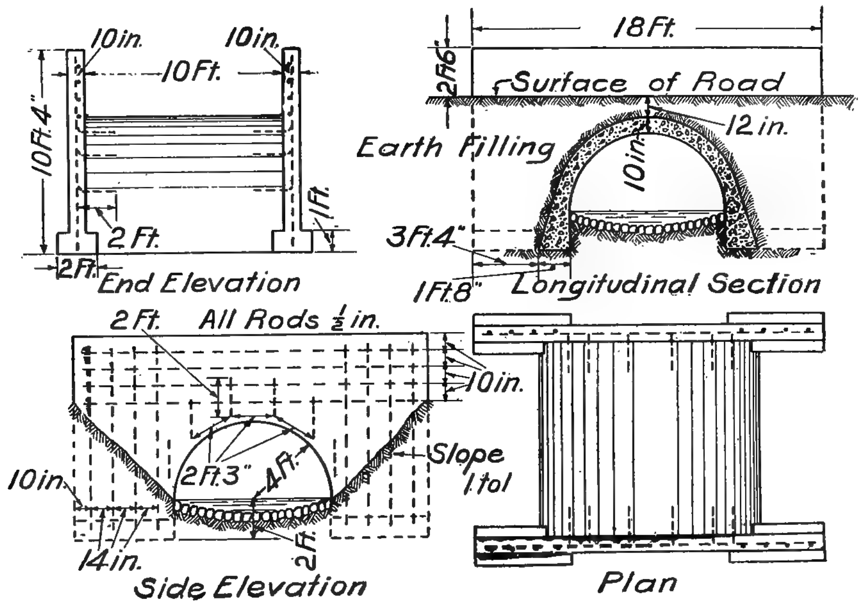


FIG. 39.—ARCH CULVERT FOR EIGHT-FOOT SPAN.

Thus, if the roadway were 16 feet wide instead of 10 feet the total volume of concrete in the culvert is 8.5 plus 0.473 multiplied by 16; that is, 8.5 plus 7.57 or 16.07 cubic yards.

The quantities of materials for arch culverts, 5, 8 and 10-foot span, are given in the following table.

QUANTITY OF MATERIAL FOR ARCH CULVERTS

Proportions: 1 Part "ATLAS" Portland Cement to 2 1-2 Parts Sand to 5 Parts Gravel or Stone

	Materials for Culvert for 10-ft. Roadway (See Figs. 37, 38 and 39)			Extra Material for Each Additional Foot Width of Road		
Span of Culvert	Cement	Sand	Screened Gravel or Stone	Cement	Sand	Screened Gravel or Stone
feet		cu. ft.	cu ft.		cu. ft.	cu. ft
5	50 bags or 12 ½ bbls.	120	240	2 bags or ½ bbl.	5	10
8	80 " " 20 "	190	380	3 " " ¾ "	7 ½	15
10	115 " " 28 ¾ "	275	550	4 " " 1 "	10	20

PREPARING THE BED.

Culverts should be built when the water is low in the brook at the site of the culvert. In many cases the water will cause no trouble if in excavating for the foundation the earth is thrown up into two parallel dams so that the brook can flow between them, the foundation for the culvert being then laid outside of these piles of earth. Sometimes the stream can be carried in a new trench around the side. If there is considerable water in the brook and it cannot be carried around, it may be necessary before excavating to drive a row of closely fitting boards parallel to the stream in front of each of the proposed trenches in which the foundations are to be laid and then bank the earth against the boards to make two tight dams between which the brook flows and behind which the work may be carried on. Sometimes the water may be carried in a box trough as shown in Fig. 41.

In some cases a hand pump may be needed to keep down the water in trenches. Trenches for foundations of whatever kind should in all cases be excavated to a depth below frost, but if the brook is never dry two or three feet below the bed of the stream will be sufficient.

The preparation of the bottom of the trenches to receive the concrete footings of the culvert as a rule should not be difficult, for the concrete can be laid directly on the soil when it is hard clay, compact sand or gravel. If the soil is soft sand or soft clay or loam it should be compacted by ramming, but if too soft to be rammed the bearing power of the soil can be increased by adding a layer of clean sand, cinders, or broken stone before ramming. In extreme cases, where the soil is very soft, it may be necessary to increase the width of the base of the culvert walls or to build these walls on a layer of 4-inch planks to distribute the weight over a considerable area of the soil.

Occasionally, piles may be necessary. Where the soil is as soft as here indicated a box culvert is preferable to an arch.

Planking should never be used under a foundation unless it will at all times be covered with water.

FORMS FOR ARCH CULVERTS.

The forms are set after the soil has been prepared to receive the concrete. Outer wing wall forms are generally constructed of 1-inch boards laid horizontally and braced with 2 by 4-inch or 2 by 6-inch studs. The forms on the inner side of the wing walls are laid horizontally and cut to fit approximately the shape of the arch. The outer surface of the arch proper needs forms from the bottom up to about ½ to ¾ of the way to the top and should be made of 1 by 4-inch or 1 by 6-inch boards, attached at their ends to the inside wing wall forms.

Centering for circular arch culverts is shown in Figs. 40 and 41. The sills should be set first and braced; then the circular forms, spaced 2 feet apart for 1-inch lagging, 3 to 4 feet apart for 2-inch stuff, should be set upon the wedges resting on the upper sills. The lagging shown in the drawings, which should be of narrow width to fit the circle, is then fastened to the circular centers. The outer forms must be braced by tieing across the top of the culvert or by using braces against the earth on either side.

In Fig. 41 the inside wall forms have a 3 by 4-inch or a 4 by 4-inch ranger set across the top of the cleats on which the wedges are placed to support the arch forms. The wedges should separate the two forms at least 3 inches in order to facilitate the removing of the arch forms. A strip of sheet iron may be nailed to the side forms, as shown, and lap over on to the arch form to prevent the concrete from getting in between the forms. After removing the arch forms the side forms can be readily removed.

The forms should be oiled before placing the concrete.

The concrete for culverts should be of a mushy consistency and should be deposited and lightly tamped in layers 6 or 8 inches thick. If possible the concrete of the whole arch and wing walls should be deposited at one time, but where the work is so large as to make it impossible to do this, the arch should be divided into circular sections, and one section laid at a time. Twenty-eight days should be allowed for the concrete to set, after which time the wedges are knocked out and the centers removed. The earth filling can be placed as soon as the connecting is completed.

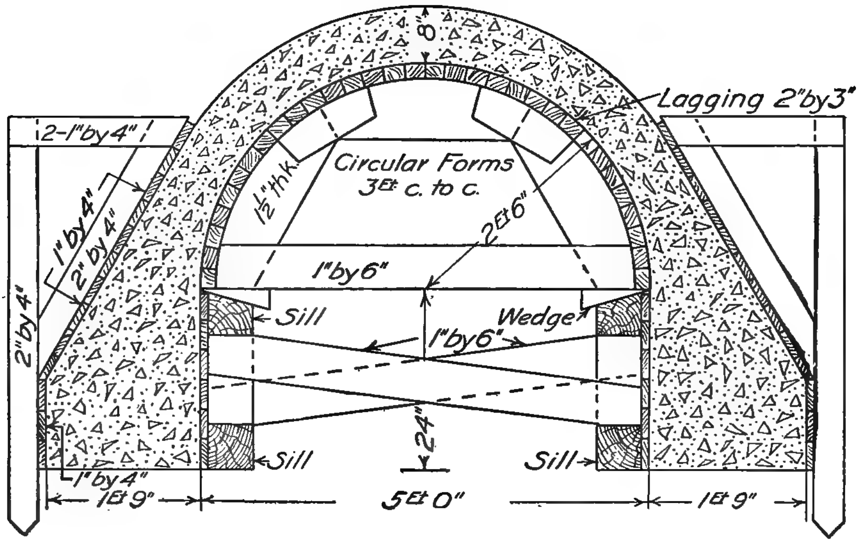


FIG. 40.—FORMS FOR FIVE-FOOT CIRCULAR ARCH.

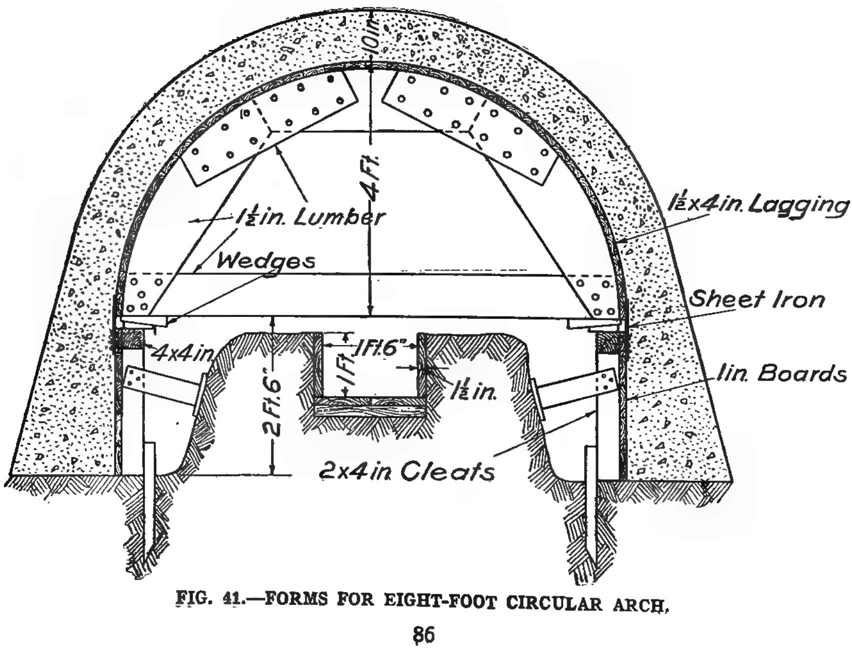


FIG. 41.—FORMS FOR EIGHT-FOOT CIRCULAR ARCH.

CHAPTER VI.

BEAM BRIDGES

Owing to the demand for more permanent bridges, concrete is fast replacing wood and steel for structures of all types, especially for spans under 100 feet. Not only is concrete an excellent material for these short spans, but where the foundations are good, concrete arches are well suited even for structures 200 feet in length or even longer. The average life of a wooden bridge is only about 9 years, and of a steel bridge not over 30 to 40 years, and

FIG. 42.—CONCRETE BEAM BRIDGE.

even during this time there is a continual outlay for repairs and painting. A concrete bridge will last indefinitely and with practically no maintenance.

In the State of Illinois alone $1,888,724 was expended for highway bridges in the year 1905, a considerable part of this being devoted to repairing and replacing wooden or metal structures. It is evident that more attention should be given to the design and construction of highway bridges.

In addition to their natural permanence, concrete bridges are cheap in first cost and are absolutely proof against tornadoes, high water, and fire. *Further-*

more, by employing local labor the money spent in their construction remains almost entirely in the community in which the bridge is built, there is less difficulty in securing the necessary skilled labor during times when the building trades are active and there is no waiting for structural steel since rods can be had at short notice.

The greatest care should be taken in the design and construction of concrete bridges. Designs must be made by an engineer familiar with concrete construction except for small arched structures where the designs given in this book may be used by one who thoroughly understands the use of concrete.

KINDS OF CONCRETE BRIDGES.

Concrete bridges may be classified as flat bridges and arch bridges. Flat bridges are those in which the pressure from the bridge acts vertically on the supports and consist either of straight flat slabs or of combined beams and slabs of concrete reinforced with steel. Arch bridges are curved and the pressures upon the supports are not vertical but inclined.

Flat construction is suitable in level countries for short spans, generally not exceeding 30 or 40 feet, and for locations where the foundation is soft material. Arches are especially economical in localities where the roads can be built considerably above the streams and where there is rock, firm sand or gravel or other similar hard soils which afford good foundations.

TYPES OF FLAT BRIDGES.

Flat bridges may be divided into three types, slab, combined beam and slab, and girder bridges. The first two types are used for short spans and the girder type is preferably used for spans from 25 to 40 feet.

A slab bridge, Fig. 43, consists essentially of a flat slab of concrete of uniform thickness reinforced with steel and resting on the supporting walls. In some cases, as shown in Fig. 44, the slab is supported by two longitudinal girders. The macadam roadway is laid directly on the slab—or by employing method and materials described in Chapter III the slab may form a concrete pavement.

Combined beam and slab bridges, Fig. 45, consist of a series of reinforced concrete beams, laid parallel to the roadway, and a flat slab of concrete upon which the roadway is laid. These beams rest on, and are usually thoroughly united with, the abutment walls. The beams and slab must be laid at one time so as to form a homogeneous structure.

Girder bridges, Fig. 48, are usually composed of two large reinforced concrete beams, called girders, one on either side of the roadway supporting intermediate cross beams which in turn carry the slab upon which the roadway is laid. A weight on the roadway, as from a wagon wheel for example, is therefore transmitted from the roadway to the slab, then to the beams, then to the girders and finally from the girders to the supports.

PROPORTIONS FOR CONCRETE.

For bridges such as described in this chapter, the concrete should be mixed one part "ATLAS" Portland Cement, two parts sand, and four parts broken stone or gravel for slabs, beams, girders, and other parts of the deck. For abutment walls and foundations use one part "ATLAS" Portland Cement, two and one-half parts sand, and five parts broken stone or gravel.

The materials must be thoroughly mixed and must not be separated in handling.

Care must be taken to work the concrete in between and around the steel rods without displacing them.

The forms must be strong and under the bridge they must be left in place 28 or 30 days or even longer in the fall and spring.

STEEL REINFORCEMENT.

The reinforcement shown in the designs of this chapter is medium steel, either with round or deformed surfaces, the latter giving better bond with the concrete.

SLAB BRIDGES.

A slab bridge similar to that shown in Fig. 43, representing a design practically the same as the standard design of the Pennsylvania State Highway Department, is of simple construction and permanent character. This bridge, which has a clear span of 16 feet, consists of a reinforced slab 15 inches thick connected rigidly to two abutment walls of the same thickness. The side walls serve only as protecting parapets. The principal reinforcement in the slab consists of steel rods ¾ inch square, spaced 5 inches apart on centers, running lengthwise of the roadway and bent at the abutments. The design shown differs from the standard of the Pennsylvania State Highway Department in that alternate bars are bent upward at the junction of the slab and abutment walls so as to lie near the outer surfaces of the slab and wall. Rods placed in these positions at the upper corners prevent cracks from forming in the concrete at the top of the slab near the abutment wall. In addition ½-inch square

rods are used in the slab, abutments, and side walls as shown in the cut. The distance from the bottom of slab to top of upper footing course is shown as 6 feet, but this may be increased to 10 feet if necessary to give the proper waterway. For greater heights than 10 feet, the thickness and reinforcement of the walls and footings should be increased. The total length of each side wall also must be increased 3 feet for every 1 foot increase in the height over that shown in the cut.

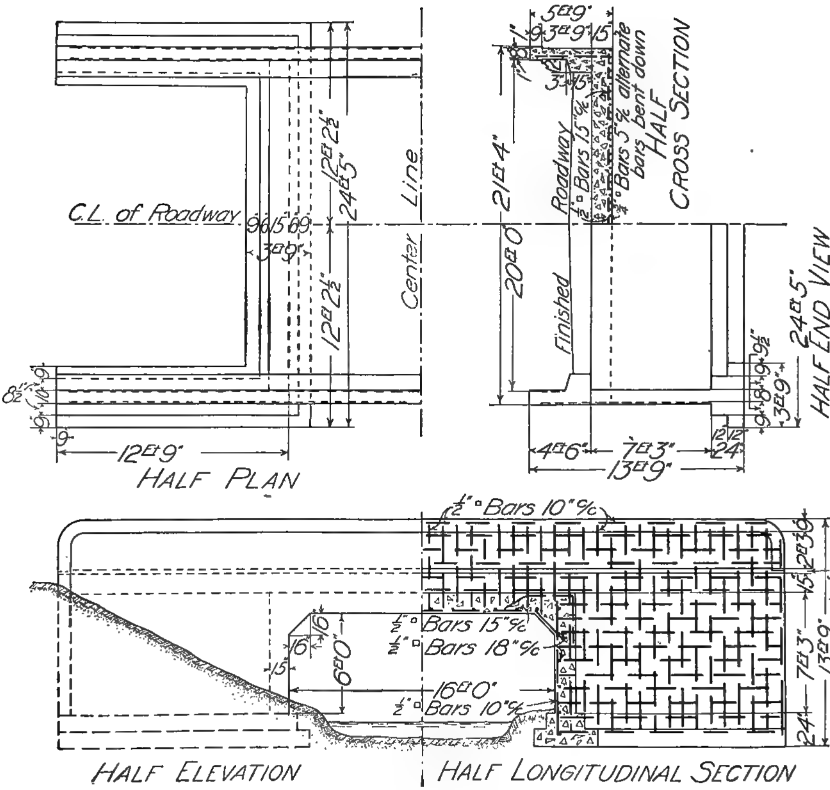


FIG. 43.—SLAB BRIDGE WITH SPAN OF 16 FEET.

The designs for spans other than 16-foot, differ in the thickness of the concrete and in the amount of reinforcement. Each span is a special design in itself and it is just as necessary to have exactly the correct amount of concrete and steel rods for each individual design as it is to use the right size of I-beams or trusses in a steel bridge.

The clear width of the roadway in the design illustrated is 20 feet, but this may be changed to suit local conditions, using for a 16-foot span the same thickness of slab and the same size and spacing of reinforcement. There are 73 cubic yards of concrete and 4,375 pounds of steel rods in this bridge. For every 1-foot increase or decrease in width of roadway, there will be an increase or decrease in the volume of concrete of 1.91 cubic yards, and in the weight of steel rods of 125.7 pounds. With the aid of these figures, the total quantities may be computed for a bridge having a roadway whose width differs from that shown in the drawing.

The accompanying table shows the proper dimensions and quantities of materials for slab bridges similar to that illustrated in Fig. 43. The quantities of materials given in the table are for the entire bridge, including abutments, sidewalls and slab.

PRINCIPAL DIMENSIONS AND QUANTITIES OF MATERIALS FOR SLAB BRIDGES SIMILAR TO BRIDGE IN FIG. 43

Clear Span in Ft.	Thickness of Slab in Inches	Longitudinal Bars		Abutment Walls		Length of Side Walls, Feet		Cu. Yds. of Concrete		Pounds of Steel Rods	
		Size of Square Bars, Inches	Distance c. to c., Inches	Thickness, Inches	Width of Footing, Inches	6 Ft.*	8 Ft.*	6 Ft.*	8 Ft.*	6 Ft.*	8 Ft.*
8	9	5/8	6	8	20	32.0	38.0	43	53	2715	3440
10	11	3/8	5	11	23	34.5	40.5	49	60	3195	3880
12	13	5/8	5	13	27	37.0	43.0	57	69	3420	4100
16	15	3/4	5	15	45	41.5	47.5	73	87	4375	5035

*Distance in feet from top of footing course to bottom of slab.

A slightly different style of design for a slab bridge from that just described is shown in Fig. 44, which represents a standard design of the Illinois State Highway Commission for a 24-foot span carrying a roadway 16 feet wide. Here the slab is supported by the side girders which at the same time serve as side railings or parapets. The wing walls are set at an angle with the abutments and are reinforced with ½-inch rods laid horizontally near the front face and vertically near the back face. The main abutment walls are 14 inches thick and have a maximum height of 14 feet 4 inches from the bottom of the foundation. These walls as well as their foundations are reinforced with ½-inch bars as indicated in the figure.

The floor slab is 11 inches thick and is reinforced with ¾-inch bars, 4 inches apart on centers running across the roadway and bent up into the gir-

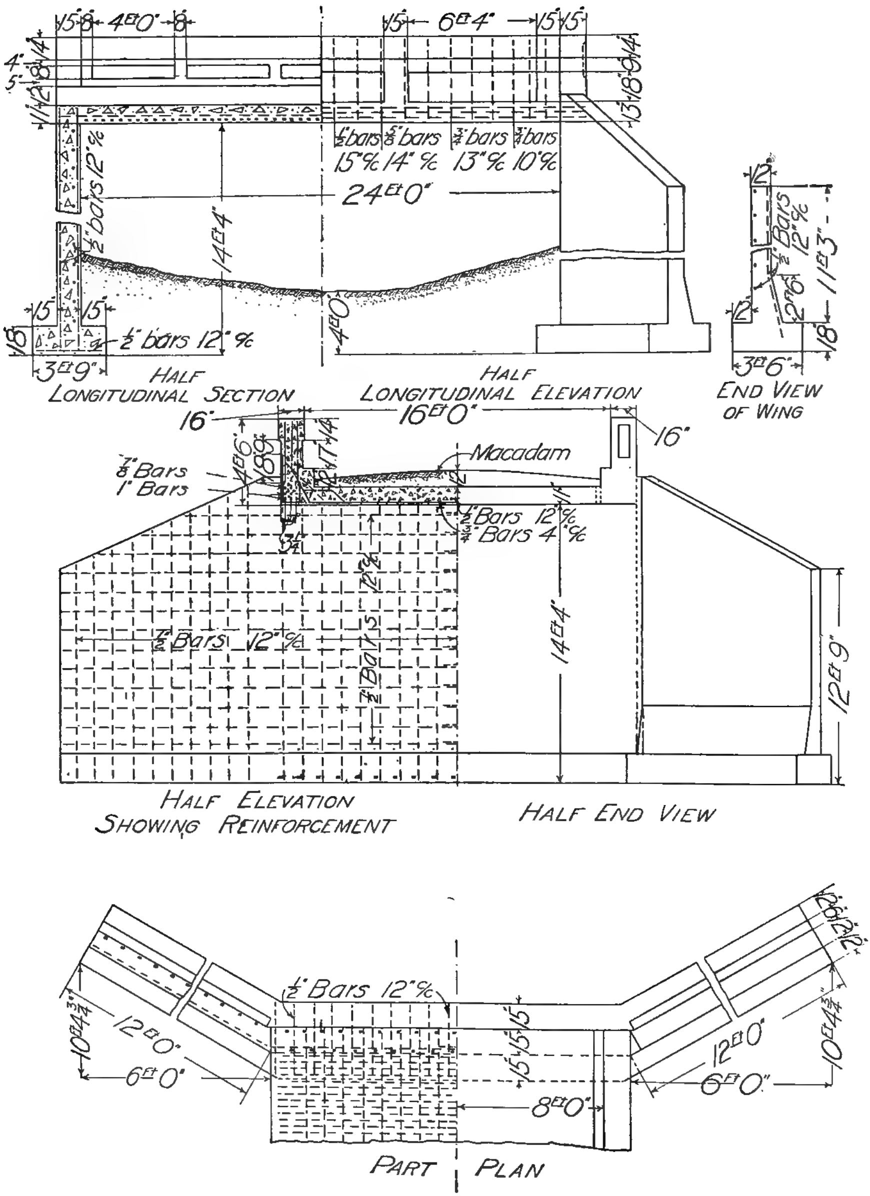


FIG. 44.—SLAB BRIDGE WITH SPAN OF 24 FEET.

ders, also with ½-inch bars spaced 12 inches apart on centers running lengthwise of the bridge. The reinforcement of the girders consists of nine horizontal bars imbedded in the lower part and several U-shaped bars placed vertically at short intervals throughout the length of the beam.

Care must be taken to set the steel rods in the places called for by the plans; thus, in the footings of the abutment walls the horizontal rods must be near the bottom, not the top of each footing. Rods are placed in concrete to perform certain definite purposes and too much care cannot be taken to see that they are set right and that they do not get moved out of place during the progress of the work.

In this 24-foot span, shown in Fig. 44, there are 82.7 cubic yards of concrete and 7,584 pounds of steel.

COMBINED BEAM AND SLAB BRIDGES.

Combined beam and slab bridges are more complicated in design and in construction than are slab bridges. Inexperienced persons should not attempt the design of structures of this type and those ignorant of the use of concrete should not attempt to build beam and slab bridges.

Combined beam and slab bridges are well adapted to spans of 15 to 30 feet where the width of roadway is more than 16 or 18 feet. Fig. 45 shows such a structure built of reinforced concrete in 1906 by the Massachusetts Highway Commission and represents a skew bridge of 28-foot span. The slab on which the macadam roadway is laid is 4 inches in thickness and is reinforced with ¼-inch square twisted steel rods spaced 8 inches apart. The slab is supported by eight reinforced concrete beams spaced 3 feet 2 inches apart on centers. These beams are 28 inches deep under the slab and vary in width from 13 inches on the bottom to 14 inches just under the slab. The reinforcement for each beam consists of three longitudinal 1¼-inch square twisted rods placed near the bottom with ten ⅜-inch and six ¼-inch stirrups placed as shown in the longitudinal section of beam.

In the construction of concrete beams, such as that shown in Fig. 45, running parallel with the roadway and resting upon the abutment cross walls, the best design demands that one or more bent bars be placed in each end of each beam running vertically into the wall near the back face and horizontally into the beam near the top surface of the beam. Bent rods of this kind tend to prevent the formation of cracks in the upper surface of the beam near the ends. In the longitudinal beams in Fig. 45, this can be done by bending up the center 1¼-inch bar about 3 feet from the face of each abutment and

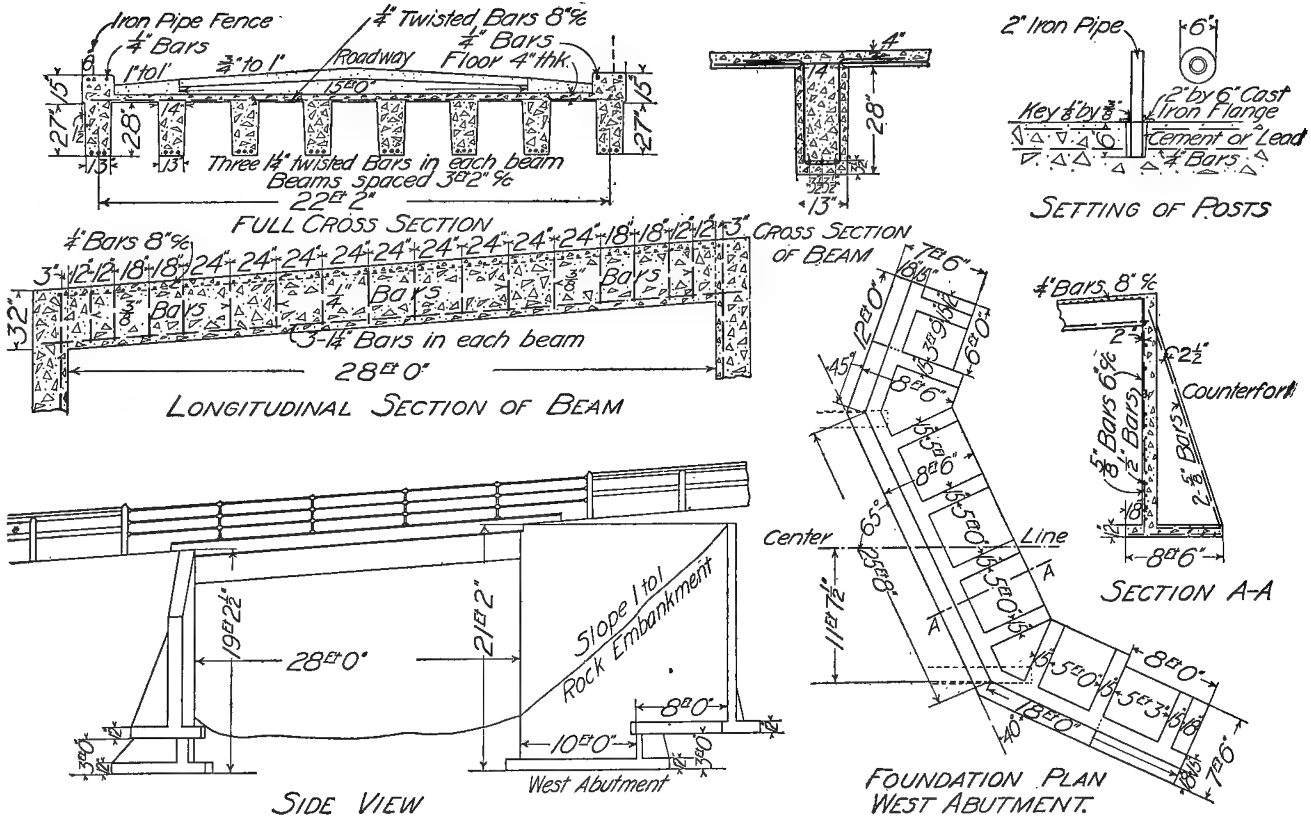


FIG. 45.—COMBINED BEAM AND SLAB BRIDGE WITH SPAN OF 28 FEET AT BECKET, MASS.

continuing this bar near the upper horizontal surface of the beam thence around the corner down into the abutment walls about 4 feet.

The abutments, Fig 45, which are irregular in shape on account of the skew on which the bridge crosses the stream, are braced with counterforts 15 inches thick spaced about 5 feet apart. Each counterfort has two 5/8-inch tie bars imbedded 2½ inches in from the back surface and bent down into the footing so as to form a secure tie. The footing is also reinforced with 3/8-inch bars running perpendicular to the face of the abutment and spaced 12 inches apart on centers. The abutment and wing walls are 15 inches thick and have ½-inch horizontal bars spaced from 12 to 24 inches apart on centers and 5/8-inch vertical bars 6 inches apart on centers.

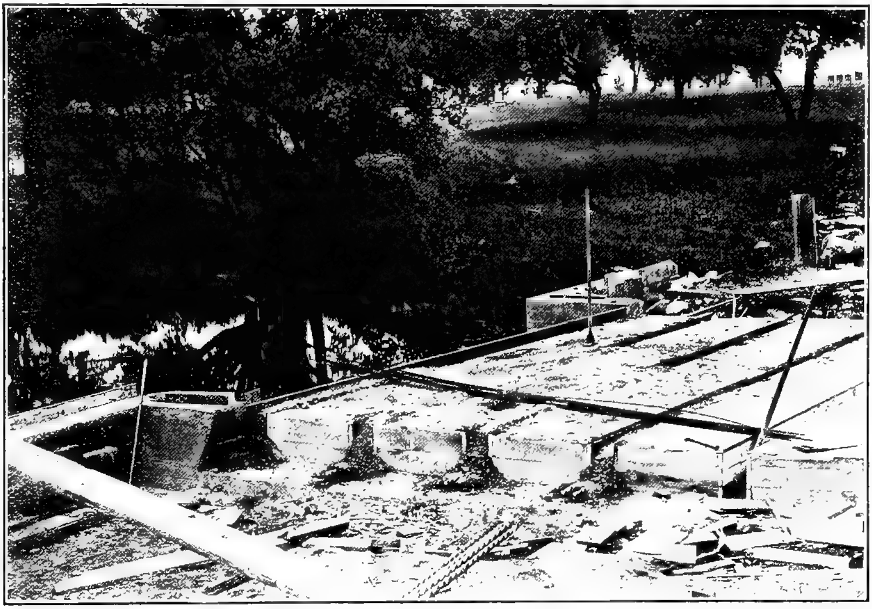


FIG. 46.—FORMS FOR SLAB AND BEAM BRIDGE.

One hundred and seventy-seven cubic yards of 1:2:5 "ATLAS" Portland Cement concrete were used in the construction of this bridge. The total cost of the bridge was $2,286.50, the cement costing $2.30 at the nearest railroad station. The actual time of construction was 54 days, although the total time elapsing from start to finish of the work was 86 days.

In concreting a combined beam and slab bridge, the work must be continuous so that the beam and slab are placed at one time, thus forming a monolith. This is a very important matter and utmost precautions must be taken to see that it is carried out in the construction of beam and slab bridges.

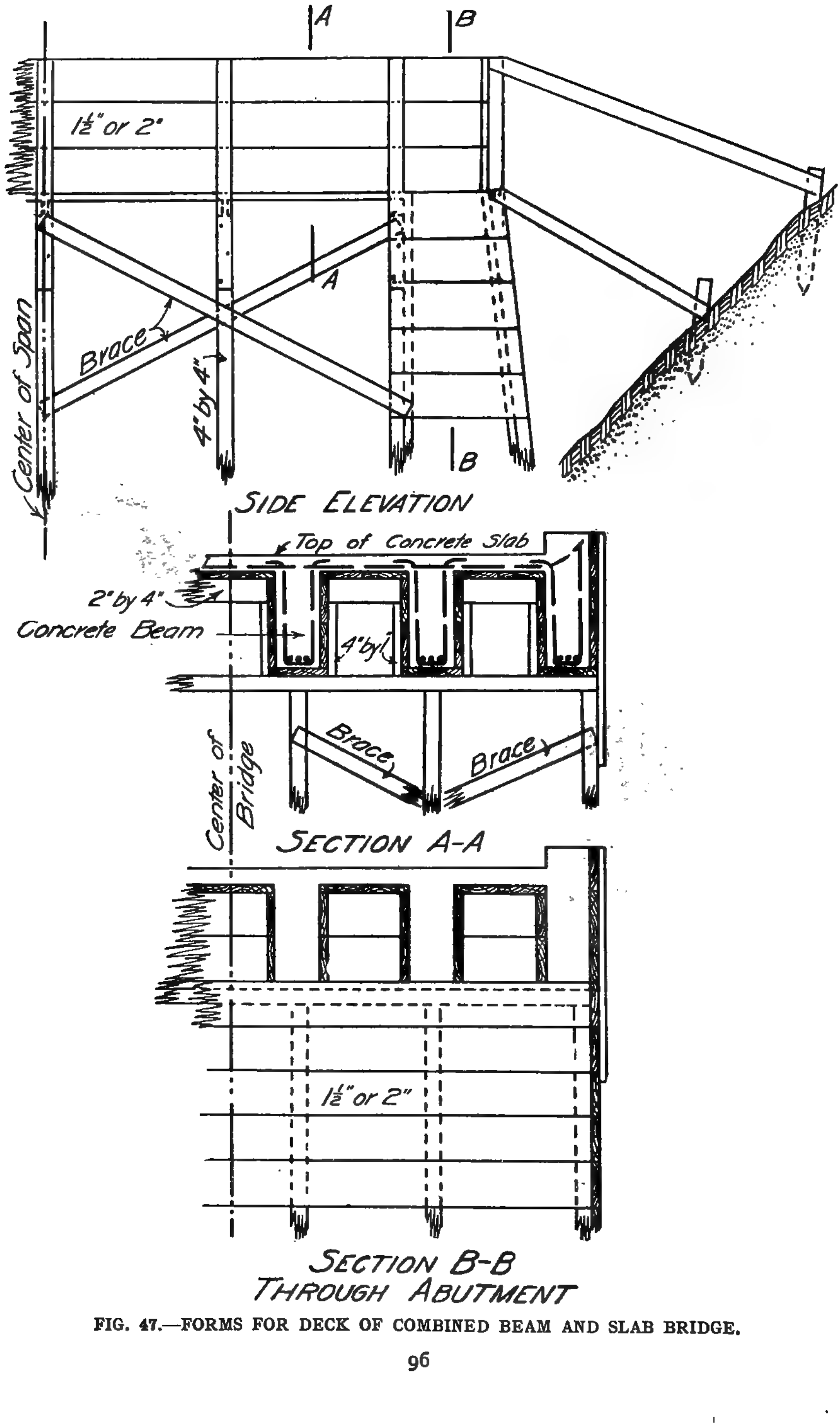


FIG. 47.—FORMS FOR DECK OF COMBINED BEAM AND SLAB BRIDGE.

METHOD OF CONSTRUCTION OF COMBINED BEAM AND SLAB BRIDGES.

Fig. 47 shows the arrangement of forms for the deck of a combined beam and slab bridge. Generally the abutment forms are first set and the concrete placed to the grade of the bottom of the beams in the deck. The forms for the deck are then put into position and after the reinforcement is placed the concrete for the beams and slab is laid, the concrete for the slab being placed immediately after filling the beam form below it and before the cement begins to set. In some cases where the beams underneath the slab are designed heavy enough to act alone without the aid of the slab the beam reinforcement is first placed and the concrete for the beams poured into the forms. Then the slab reinforcement is placed in position and the concreting of the slab started. If, however, the beams are designed as T-beams in the more usual and the cheapest way, it is absolutely essential that the beams and slab be laid at the same operation. The deck forms should be thoroughly braced underneath so that they will not deflect as the concrete is poured.

In Fig. 47 the bracing is only partially shown, since it will vary considerably with the location of the structure. The stirrups shown in section A-A can best be held in place temporarily with small wooden strips which are removed as soon as there is enough concrete in the beam to hold the stirrups in place.

GIRDER BRIDGES.

Concrete girder bridges are not so common as slab or combined slab and beam bridges, but they are suitable for spans longer than is proper for the slab bridges and for locations where there is not head room enough to use an arch span. Fig. 44 is in one sense a girder bridge since it has two main girders which carry the slab, but Fig. 48 gives a better idea of this type of structure. In Fig. 48 the slab is 8 inches in thickness at the center and 7 inches at the girders and is reinforced with ¾-inch twisted square bars spaced 7 inches apart on centers running parallel to the roadway. At the center of each panel, that is, midway between the cross floor beams, these bars must be laid 1½ inches from the bottom of the slab, but at the cross-beams they should be 1½ inches from the top of the slab, being bent to conform to these requirements. Another way is that shown in Fig. 48, where the rods in the bottom of the slab are run through straight over the floor beams and another set of ¾-inch bars 4 feet long spaced 7 inches apart on centers is laid parallel with the length of the roadway and imbedded in the top of the slab over the floor beam. At the end of the bridge where the slab connects with the end

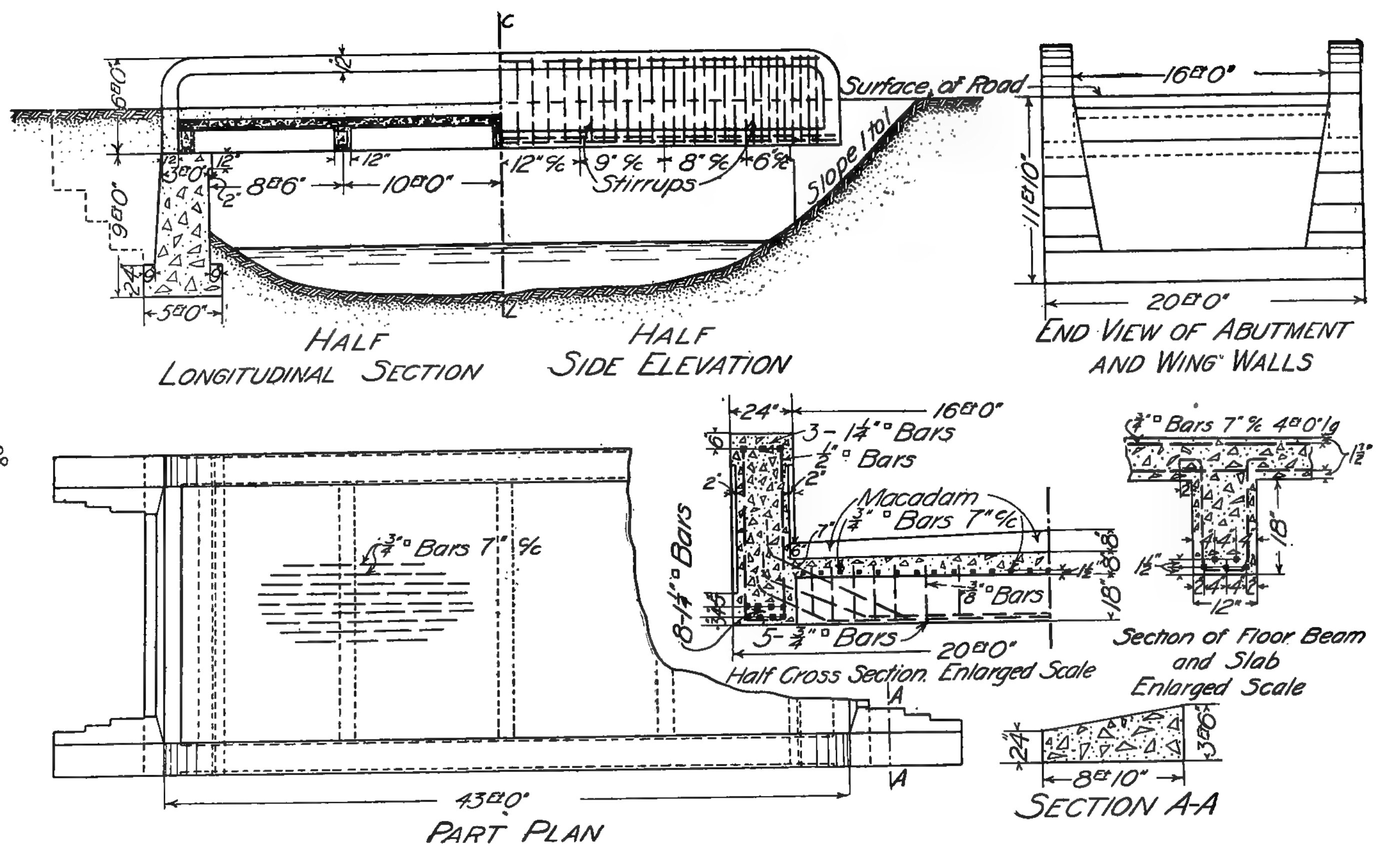


FIG. 48.—GIRDER BRIDGE WITH SPAN OF 37 FEET.

floor beam, the rods in the top of the slabs should be bent to extend downward into the floor beam.

The floor beams, which are the cross-beams running from girder to girder, are spaced 10 feet apart on centers and are reinforced with five ¾-inch longitudinal bars and with ⅜-inch stirrups. These longitudinal rods must be bent up at each of the floor beams as shown and must extend into the girder.

The main girders have a clear span of 37 feet and a depth of 5 feet. They are reinforced with eight 1¼-inch square bars in the bottom and three 1¼-inch square bars in the top and are provided with vertical stirrups. The stirrups are ½-inch bars bent U-shaped and placed close together near the ends of the girder and further apart near the center.

The surface of the roadway must be drained and this can best be done by making a slab with a curved upper surface so that the water may run to the gutters and thence through the drain pipes placed in the slab.

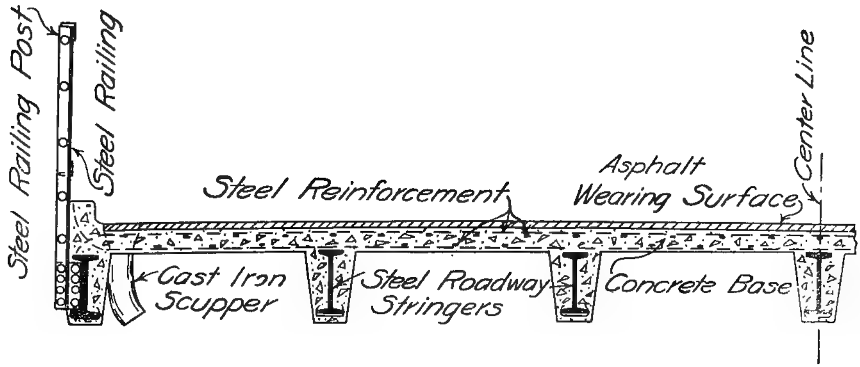


FIG. 49.—REINFORCED CONCRETE ROADWAY FOR STEEL SPANS.

CONCRETE FLOORS FOR STEEL BRIDGES.

On long span highway bridges where steel trusses are necessary, plank flooring has until recently been used, but as this planking only lasts from one to five years there is a demand for something more durable than wood and reinforced concrete slabs on steel beams are being used.

Fig. 49 shows a typical cross section of a concrete slab construction carried on steel I-beam stringers which in turn are supported by the steel floor beams running from truss to truss. A 30-foot roadway without sidewalks is here provided for, but where sidewalks are necessary the construction may be easily modified to suit. The wearing surface of the roadway is shown as asphalt, which usually is laid 2 inches thick on a binder of small thickness. In some cases the binder has been omitted and the upper surface of the concrete left

very rough to give a good union between asphalt and concrete. Proper crown must be given the roadway to take care of the drainage; this being easily done by setting the I-beam stringers on high levels towards the center of the roadway or else by making the concrete slab level and using a greater thickness of wearing surface at the center than at the gutters.

The I-beam stringers should be encased in concrete as shown, for by so doing a stronger floor is obtained and the steel beams are protected against rust. Railing posts made of two steel angles and connected to the outside I-beam by a plate and small angles, give the necessary support to the railings.

COST OF BEAM AND SLAB BRIDGES.

There is considerable variation in the cost of concrete bridges and any data given regarding the cost is at the best only approximate. The cost of a bridge is affected by the span, width, height, character and depth of foundations, the type of structure, the magnitude of the loads to be carried, the style of finish, and by several other elements of a similar nature.

The cost of several reinforced concrete bridges recently built and similar to those shown in this chapter, was $9.00 per cubic yard for the reinforced concrete where the expense of hauling was considerable, and $6.75 per cubic yard for abutments without reinforcement. The abutment foundations extended about 3 feet into the ground.

For reinforced concrete bridge work similar to that shown in Fig. 43, the contract price frequently paid by the Pennsylvania State Highway Commission is $10.00 per cubic yard.

A bridge of 30 feet span similar to the one shown in Fig. 44 and designed by the Illinois Highway Commission cost $995 not including the crushed stone which was furnished free. The price of the bridge would have been $1,125 had the contractor furnished everything. There were 90 cubic yards of concrete and 8,600 lbs. of steel in the structure.*

*Illinois Highway Commission Report, 1906, p. 59.

CHAPTER VII.

ARCH BRIDGES.

Arches include that class of curved bridges varying from simple culverts of 5 or 10-foot spans to the wonderful structures like the Walnut Lane Bridge in Philadelphia which has an arch of 232 feet, clear span. The advantage of using concrete in bridges was clearly set forth in Chapter VI. and therefore it is needless to further emphasize in this chapter on arch bridges, its value

AUBURN ST. BRIDGE, MEDFORD, MASS.

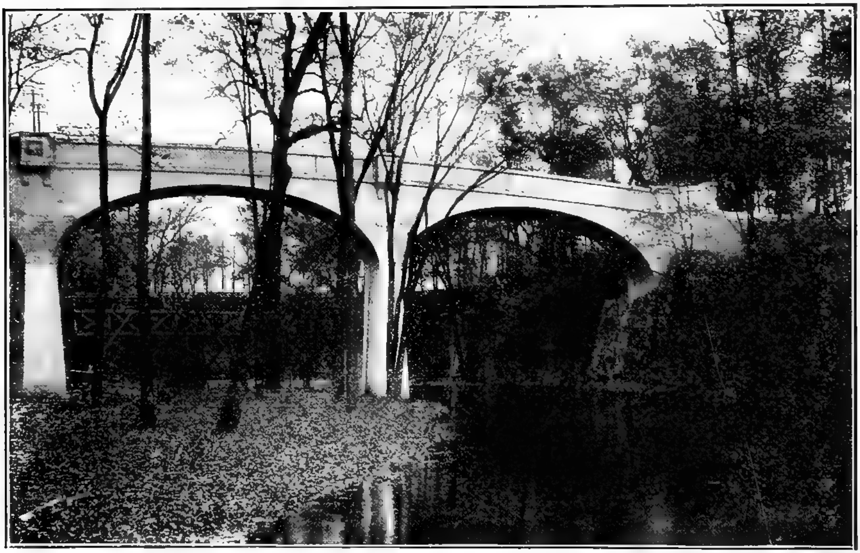
wherever ultimate economy, beauty and durability are of importance. Suffice it to say that in many locations a good concrete arch bridge can be built cheaper than a good steel bridge, and when the durability of the concrete and the enormous cost of maintaining the steel bridge are considered there is no question as to which is the better investment for a town or county to make. The concrete structure is more durable, more beautiful, and in every way superior to steel construction for spans of ordinary length. Where the foundations are good, a series of arches may be used in place of a steel bridge with long spans, and the advantages already enumerated for short spans apply equally well in this case. The pressures which the arch exerts on its foundations are

inclined and this pressure or outward thrust must be provided for in the design and construction of the bridge.

PLAIN AND REINFORCED CONCRETE ARCHES.

Arches may be built either with or without steel reinforcing bars; where there is no steel the arch is of plain concrete, and if steel rods or steel in other forms are used to reinforce the concrete the structure is then called a reinforced concrete arch bridge.

Steel reinforcements should always be used in arches, for while it adds very



BRIDGE IN DELLWOOD PARK, JOLIET, ILL.

little to the cost, it increases the strength considerably. In the last few years there has been a remarkable increase in the number of reinforced concrete arch bridges, and they are giving perfect satisfaction. In most cases the quantity of steel used is really very small in proportion to the quantity of concrete, and as this steel is entirely imbedded in the concrete it cannot rust and therefore is not open to the same objections that are raised against steel where it is exposed to the action of the elements. In many arches the cross-sectional area of the steel used is only about 1/100 of the area of the concrete as measured at the crown of the arch, which is the highest part of the span. This means that for every 100 square inches of concrete there is only 1 square inch of steel at that section.

Under ordinary conditions bridges of spans from 20 or 30 feet to 100 feet can be readily constructed of reinforced concrete, while for even greater spans where the foundations are good, the proper combination of steel and concrete makes a strong, graceful and economical bridge, a type which is being widely adopted in country districts as well as in the larger towns.

HISTORY OF CONCRETE ARCHES.

The first plain concrete arch built was the 116-foot span at Fontainebleau Forest in France, which was finished in 1869, and is known as the Grand Maitre bridge. In the United States the first plain concrete arch of which there is any record was one of 31-foot span built in 1871 in Prospect Park, Brooklyn. The earliest reinforced concrete arch in the United States was constructed in Golden Gate Park in San Francisco in 1889, and several years even before this date concrete bridges reinforced with iron had been built in Europe. This type of construction is not an experiment. It represents the highest art of modern bridge construction. As a material for highway bridges of spans from about 30 feet to 100 feet reinforced concrete has no equal.

As has already been stated, a span of 232 feet has been completed in Philadelphia. The new Rocky River Bridge in Cleveland, Ohio, is being constructed with a span of 280 feet and a proposed bridge in New York City has a span of over 700 feet. These large spans show the rapid development in the art of building bridges with concrete.

TYPES OF CONCRETE ARCHES.

Arches are classified in various ways, but the most simple classification is that which deals with the method of the construction of the spandrels which are the spaces above the upper surface of the arch ring and below the roadway level. These spaces may be either filled in solid with earth filling or they may be left open by supporting the roadway above on slabs and beams, which in turn are supported on columns or cross-walls resting on the arch ring.

Where the spandrel spaces are filled in solid with earth, this earth is prevented from flowing out sidewise by side walls, also called spandrel walls, which run lengthwise of the bridge, one on either side of the roadway. The earth rests directly on the outer surface of the arch ring and the road or street pavement is laid directly on this earth filling. These bridges are said to have solid spandrels.

In the second type, where the spandrels are left more or less open, the roadway is usually laid on a slab of reinforced concrete having a thickness of from 4 to 8 inches which rests upon a series of reinforced beams supported on col-

umns, or upon transverse concrete walls which, being spaced at distances of from 10 to 20 feet lengthwise of the bridge, give the appearance of open spandrels. These columns or walls rest on top of the arch ring.

For small arches the solid spandrel type is the most common, while for the large bridges with spans over 100 feet the open spandrels are better, because they lessen the weight to be carried.

Arches are often also classified as to the style of reinforcement or as to whether there are any hinges used in the arch ring. A hinge is made by inserting a joint in the concrete arch ring, and usually, when they are used, one is

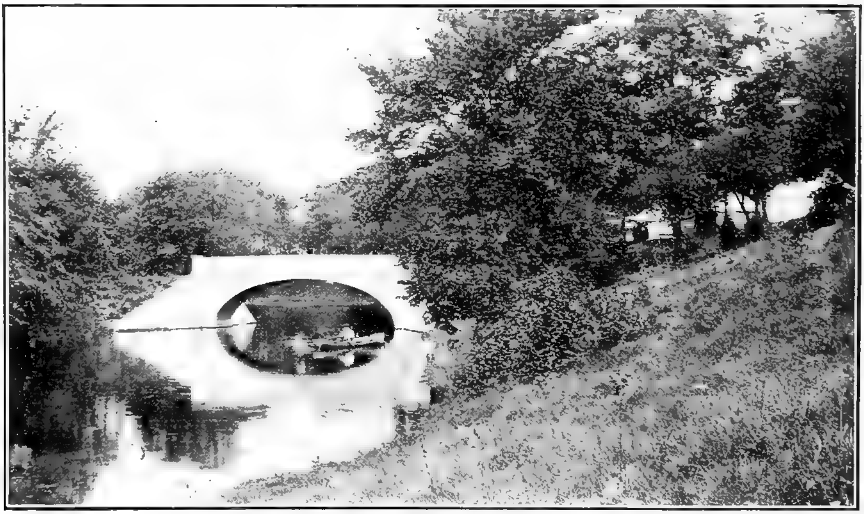


FIG. 50.—ARCH BRIDGE, DELLWOOD PARK, JOLIET, ILLINOIS.

placed at the crown of the arch and also one at each end where the arch ring rests upon the abutment or support. These hinges are made of steel and act very much in principle like the hinges on an open door, that is, the concrete arch ring can move a little by turning around the steel hinges. This movement is of course very small. Hinges are used with an idea of simplifying the design of the arch, but they have been employed in only a few cases in the United States.

PREPARATION OF PLANS.

An arch bridge is too important a structure to be placed in charge of an inexperienced man. The only safe way is to employ a competent engineer to prepare plans and specifications and to superintend the construction. Before

the contract for the bridge is let, the plans should be complete and should show not only the principal dimensions of the structure, but they should also show all important details which may in any way affect the strength or the cost. Unless the plans and specifications are complete and accurate, unnecessary delays in construction and extra charges for changes and additions will inevitably occur. If the engineer is not to be on the ground continually during the construction, he should be allowed a competent assistant or inspector whose duty it should be to see that the plans and specifications are followed and that the work is carried on in a proper manner.

DESIGN FOR A 40-FOOT SPAN.

Fig. 51 shows a design for a reinforced concrete highway arch for a 40-foot span with a rise of 8 feet. The principal parts are the arch ring, the spandrel or side walls, the abutments, the wing walls, the parapets and the earth filling. The cross section at crown shows a 20-foot roadway with a 6-foot sidewalk on either side. At the crown of the arch the earth filling has a thickness of 18 inches at the center of the roadway.

The arch ring is 12 inches thick at the crown and 2 feet 6 inches thick at the abutments, the latter being the radial not the vertical thickness. The dimensions of the abutments are shown in the drawing and have been determined on the assumption that the soil under the foundations is good compact sand and gravel or other similar materials capable of safely sustaining 4000 to 6000 lbs. per square foot.

The arch ring is reinforced with round medium steel rods ¾ inch in diameter running lengthwise of the span, arranged in two layers, one layer 2 inches in from the outer curved surface of the concrete ring and the other 2 inches from the inner curved surface. These layers, therefore, are 8 inches apart at the crown and 2 feet 2 inches apart at the abutments. The rods in each layer are 8 inches apart on centers as shown in the cross section.

In addition to the ¾-inch rods there are two sets of ½-inch diameter rods running at right angles to the length of the roadway as shown in the one-half longitudinal section. In each layer the ½-inch rods are 15 inches apart on centers. Stirrups made of ⅜-inch diameter round rods are frequently used in bridges of this type to connect the outer layer with the inner. They should be hooked at the outer and inner ends to pass around the transverse and longitudinal rods at their intersections. In the bridge shown, this arrangement would space them 15 inches apart. Where no stirrups are used, the transverse and longitudinal rods should be connected by wires at their intersections.

Where the design calls for rods longer than can be obtained in one length, splices must be used and this can be done by simply lapping the two bars to

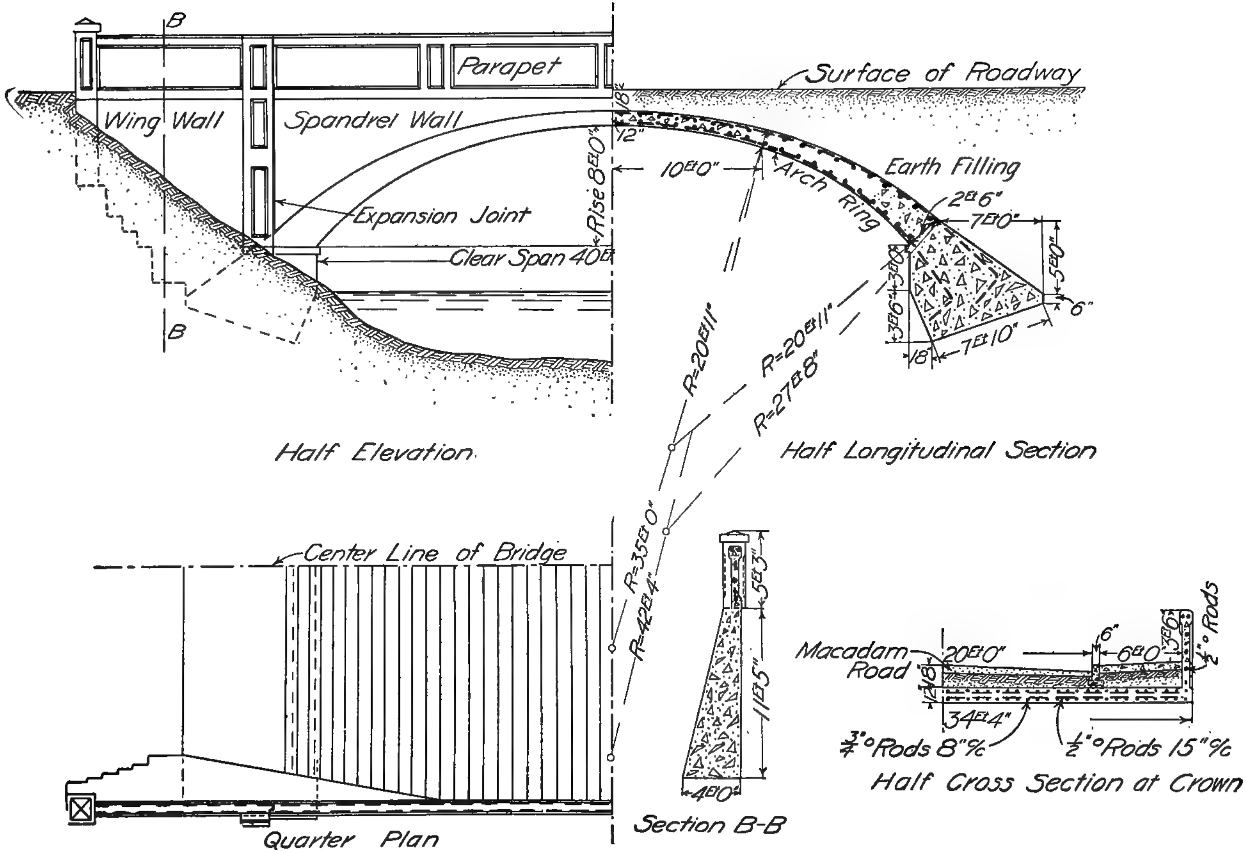


FIG. 51.—REINFORCED CONCRETE ARCH BRIDGE WITH SPAN OF 40 FEET.

be spliced a distance equal to 20 diameters of the rod if it has deformed surfaces or 30 diameters if it has smooth surfaces. Sometimes the rods are lapped and then wound with heavy wire. Some designers thread the rods and splice them by means of sleeve nuts, but usually it is sufficient to lap the rods as indicated.

As shown in the cross section at the crown, Fig. 51, six ½-inch diameter rods should be placed in the parapet wall between the expansion joints.

The design shown is suitable for ordinary highway traffic.

EXPANSION JOINTS.

Each spandrel wall and parapet is provided with an expansion joint at the abutments. This is to allow for the change in length of these parts due to changes in temperature. Concrete changes its length about ⅜-inch for every 100 feet of length due to the change in temperature from a mean temperature to extreme heat or to extreme cold in a climate such as that of New England, Michigan or similar sections. Unless the wall is properly reinforced, expansion joints should be left at distances apart not much over 40 feet or even less to prevent cracking due to these changes in temperature. These joints should be made from the upper surface of the arch ring to the top of the parapet and should be made wedge-shaped or dove-tailed so that one part fits into the other.

REINFORCED CONCRETE ARCH, ELM STREET, CONCORD, MASS.

Figs. 52 and 53 show a highway bridge of 75 feet clear span built of "ATLAS "Portland Cement in Concord, Massachusetts, by the Massachusetts Highway Commission. The rise of the arch is 12 feet or about 1/6 of the span length. At the crown the arch ring is 16 inches in thickness and increases towards the abutments as shown.

The reinforcement in the arch ring consists of 1-inch longitudinal twisted steel bars spaced 17 inches apart on centers and ¼-inch transverse twisted steel bars spaced 24 inches apart on centers. The centers of the 1-inch rods are 2¼ inches from the face of the concrete and these rods are in lengths of about 16 feet lapped 40 inches at each splice as shown in Fig. 55. Reinforced side walls braced with counterforts shown in Fig. 53 serve to retain the earth filling. Although there is a comparatively small amount of concrete used in the construction of this type of wall, the saving due to this is probably more than offset by the increase in cost due to the expensive forms necessary for the counterforts. Several sections of these side walls are shown in the upper right hand corner of the drawing over the half section of the arch, and the locations of these sections are indicated by distances on the half section and

by letters upon the plan of the arch. The steel in the side walls consists of ⅝-inch horizontal rods spaced 12 inches apart on centers near the bottom and ½-inch rods spaced 24 inches apart on centers near the top of the wall. In the coping there are also two ¼-inch longitudinal rods. The counterforts are provided with tie rods as indicated.

As shown in Fig. 53, the coping overhangs the face of the arch ring and the face of the wing walls by 1½ inches, the faces just mentioned being in the same vertical plane; the spandrel walls are set back 1½ inches from the face of the arch ring, hence 3 inches back from the surface of the coping. This gives a neat design and one which is easily carried out.

Four hundred and fifty-eight cubic yards of concrete were used in this structure.

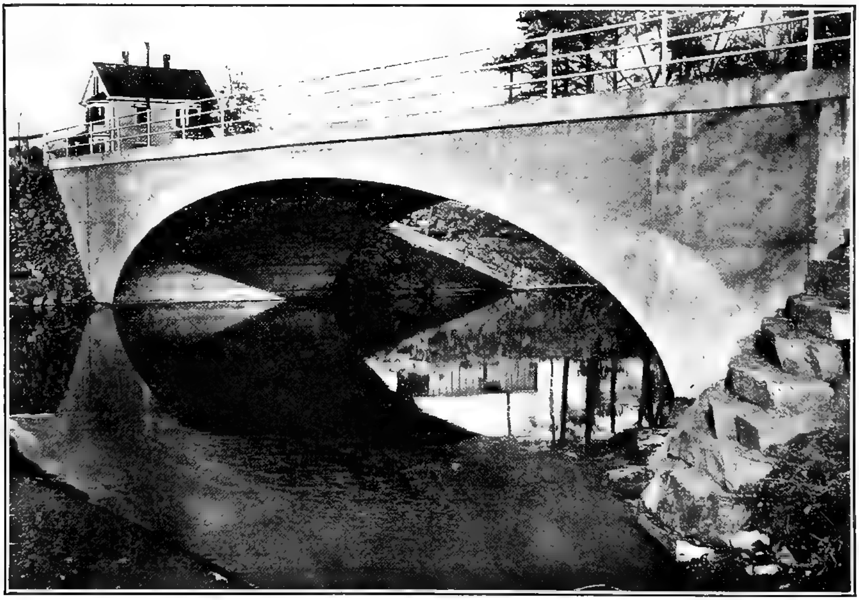


FIG. 52.—ARCH BRIDGE WITH SPAN OF 75 FEET, ELM STREET, CONCORD, MASS.

Fig. 54 on page 110 is a view taken just after the falsework and centering were in place and before the lagging was placed on the centering. The photograph on page 110 shows the arch ring under construction with the longitudinal rods partially imbedded in concrete. One of the small transverse rods may be seen just beyond the top of the transverse stop boards. These stop boards serve as temporary forms for the concrete and also as spacers for the longitudinal rods. After these boards are removed the next section of the concrete

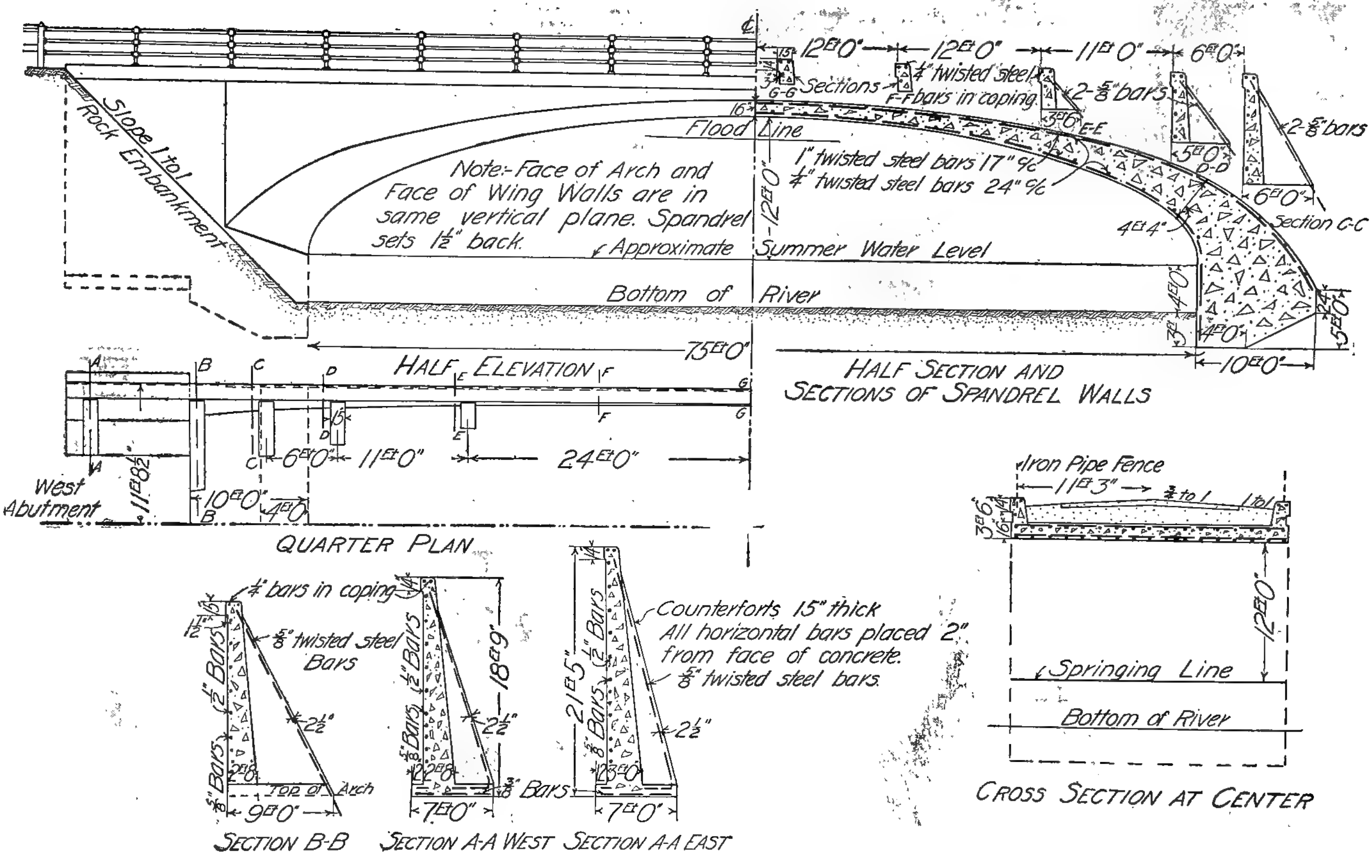


FIG. 53.—ARCH BRIDGE WITH SPAN OF 75 FEET, ELM STREET, CONCORD, MASS.

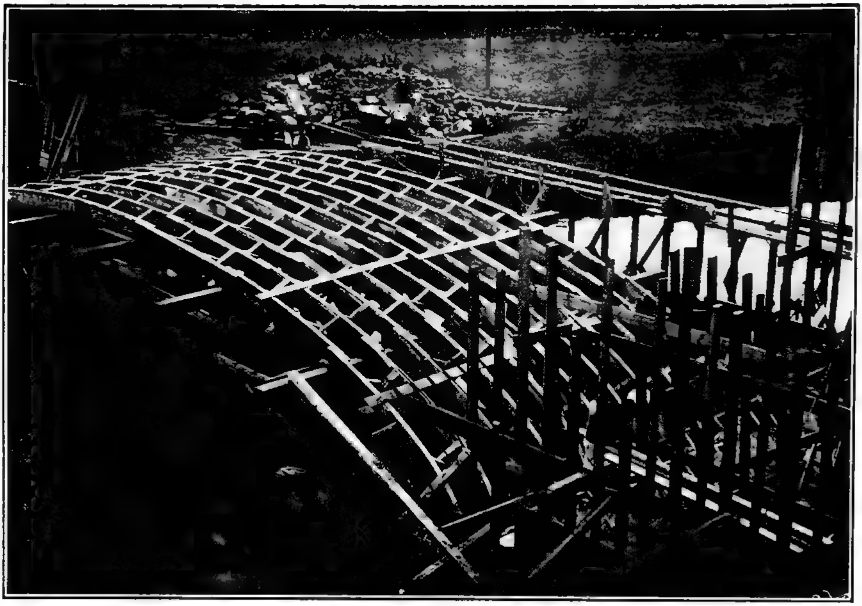


FIG. 54.—CENTERING OF ARCH BRIDGE, ELM STREET, CONCORD, MASS.

FIG. 55.—CONSTRUCTION OF ARCH BRIDGE, ELM STREET, CONCORD, MASS.

for the arch ring is deposited against the finished section. The form of arch here shown is suitable for locations where the foundation is of the hardest material, like hard pan or rock.

FALSEWORK AND CENTERING.

The falsework and centering, Fig. 56, constitute that part of the temporary wood work which supports the concrete while it is being laid and until it has hardened. The falsework consists of vertical timbers braced transversely and longitudinally upon which rest the centering or curved platform forming the support for the concrete arch ring. The vertical supports may be either piles driven into the ground or river bottom underneath if the bottom is soft, or framed trestle bents resting on horizontal timbers if the bottom is hard. The piles must be placed close enough to carry the weight above with practically no settlement and must be braced with 2 by 8-inch or 2 by 10-inch diagonal timbers spiked or bolted to the piles.

Transversely to the length of the bridge and spiked or bolted to the tops of the piles, a cap must be set and upon these caps rest wooden wedges supporting the weight of the centering above.

The centering consists usually of a set of caps or cross timbers resting on the wedges above the pile caps, some longitudinal stringers notched on and supported by the upper caps and finally of a closely laid flooring or lagging resting on the stringers. The caps for the centers are usually 10 by 10 inch or 12 by 12 inch timbers. The stringers are of varying size, depending on the distance between piles and the weight to be carried. For arches having spans up to 100 feet, these stringers are from 2 to 4 inches wide and from 12 to 14 inches deep, spaced from 1½ to 3 feet apart on centers. The upper surface of the stringers must be curved to fit the curvature of the under surface of the arch; this is frequently done by nailing a curved piece to the top of the stringers as in the centering of the Concord Arch in Fig. 54 and also in Fig. 56. The stringers must be braced to one another by 1 by 6-inch bridging as is common in ordinary house floors.

Lagging, consisting of ⅞-inch tongued and grooved pine or 2-inch spruce with beveled edges, must be nailed to the stringers and must be planed on the top side to give a smooth finish to the under surface of the arch ring. Sometimes where the stringers are quite far apart 4-inch lagging is used.

PLACING CONCRETE.

Before concreting is begun, the forms for the foundations and wing walls should be in place and thoroughly braced and the steel reinforcement set and wired in place. The forms and steel for the spandrel walls and the arch ring

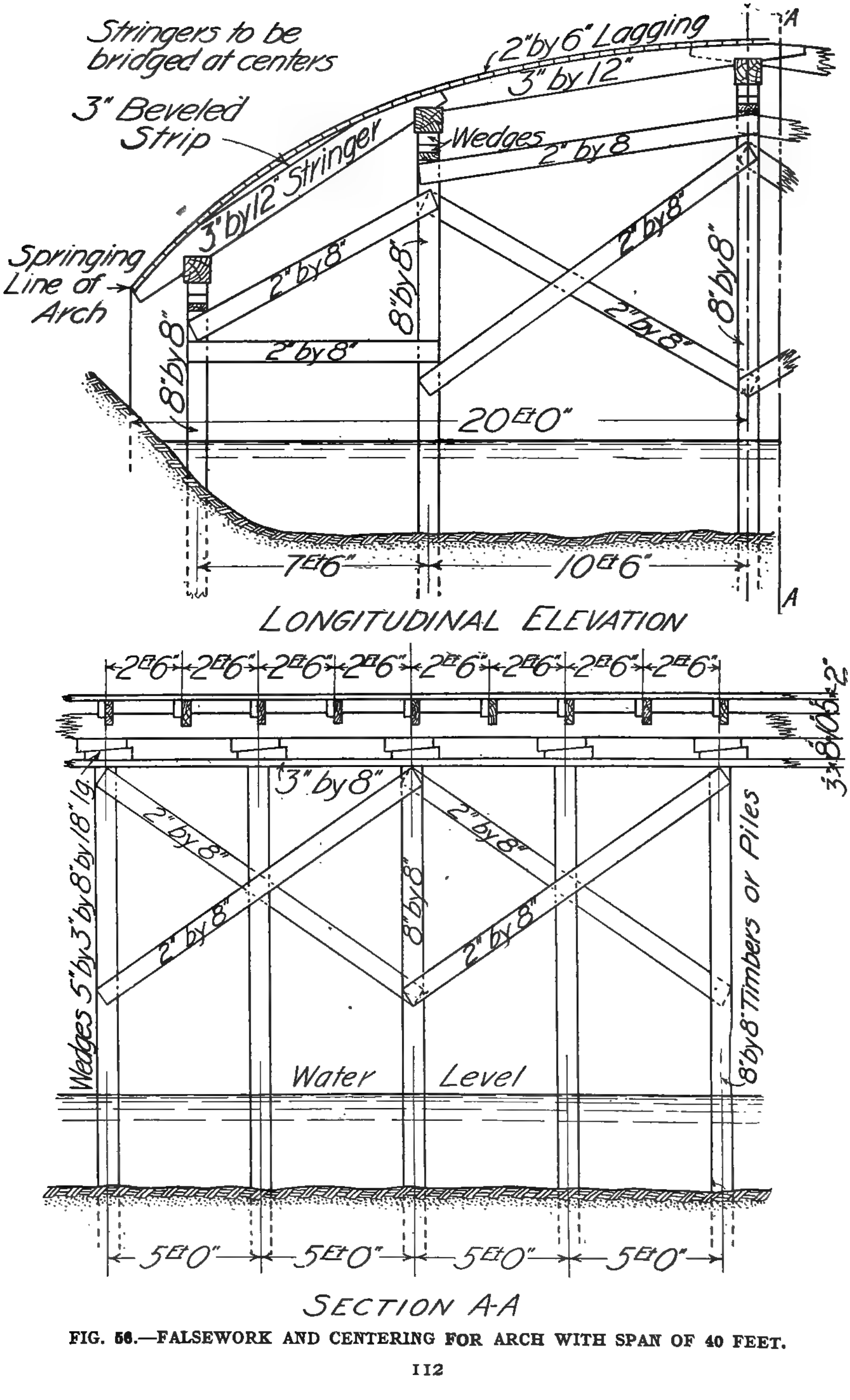


FIG. 56.—FALSEWORK AND CENTERING FOR ARCH WITH SPAN OF 40 FEET.

may be placed while the concrete is being deposited for the foundations. As soon as the concrete in the foundations is up to the arch, the arch may be begun and laid in one or two days.

First, the arch ring may be divided longitudinally into parallel rings or sections having a width of from 3 to 5 feet, or even more if the span is not too large, and one of these sections laid at a time. This is generally the best plan to follow.

Or, secondly, the arch ring is divided into sections as shown in Fig. 55, which shows the Concord Arch being laid in large, separate blocks across the

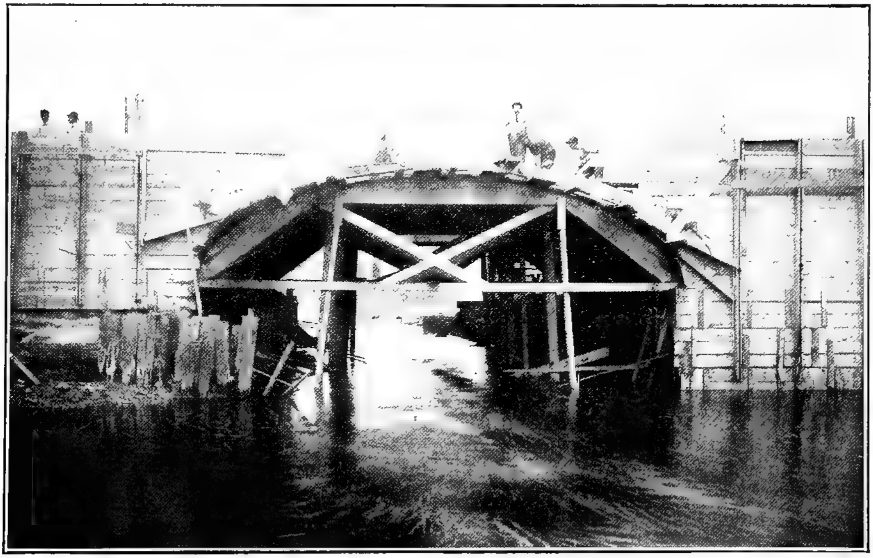


FIG. 57.—CENTERING FOR ARCH IN PLACE.

bridge, having a width equal to that of the arch ring and a length equal to a fraction of the span length.

Whichever of these methods is used, care must be taken to avoid undue settlement or distortion of the centers as the concreting progresses. If the second method of laying concrete is used, that is, in large transverse blocks, the work is usually begun at each abutment at the same time, and if the centering is not well supported underneath it will rise at the crown, due to the weight at the two ends. To avoid this the best way is to begin concreting at the two abutments and as this work progresses load the centering at the crown temporarily, adjusting this load if needs be to keep the centers in proper position. The loading at the crown is frequently done by laying a part of the arch ring there

after a part is laid at each abutment. Then the spaces between these blocks are filled in.

For small arches the entire ring can be laid in one day's work, and of course this should be done whenever possible.

EARTH FILLING.

After the concrete is placed in position and thoroughly hardened and before the centers are removed, the earth filling should be added. As the earth is placed, it should be compacted by ramming or rolling, and even if the centers are still in place it is better to deposit the earth in layers over the whole length of the span so that the arch is loaded nearly uniformly till the entire filling is in place.

If the filling is placed after the centers are removed, it is absolutely necessary to place the earth uniformly over the span length and not pile a large weight on one side leaving the other side unloaded.

In case the finished roadway is to have a surface such as macadam or concrete, great care should be taken in compacting the earth filling, for otherwise settlement will take place in the filling and the roadway surface will also settle.

STRIKING CENTERS.

By striking centers is meant the lowering of the centers so that the arch becomes self supporting. The centers are usually lowered by removing the wooden wedges already mentioned under the head of Falsework and Centering. These wedges, Fig. 56, placed between the caps of the falsework and those of the centers, can be removed by a sledge hammer, thus lowering the centers. Care must be taken to lower the centers gradually and without jarring the structure by allowing a part to get its load suddenly.

SURFACE FINISHING.

In many structures the appearance of the surface of the finished concrete is of no importance, but most structures, such as bridges, which are constantly exposed to view, need some treatment to render the outer surfaces neat in appearance. Oftentimes the structure is such that proper selection of good tongued and grooved planking smoothly laid, together with care in placing the concrete against the forms is all that is required to give a fairly presentable surface. This surface is obtained by simply forcing a spade down the side of the forms and pushing back the stones so that the mortar will flow against the face of the forms and fill all stone pockets or voids.

If a better finish is desired, good results can be obtained by removing the

forms before the concrete has set very hard, generally from 12 to 48 hours, depending upon the cement, weather and amount of water used in mixing, and after floating the green concrete with water by rubbing the surface with a circular motion with carborundum bricks or with bricks composed of 1 part "ATLAS" Portland Cement to 2 parts sand. If the concrete can be worked when quite green, a very satisfactory finish can be obtained by rubbing the surface with stiff wire brushes.

When the surface of the concrete has set so hard as to prevent its being treated by rubbing with a brush, it still may be surfaced with a carborundum block, or an excellent finish may be gained by picking the concrete surface with a hand or pneumatic tool after the forms are removed. If further treatment is deemed necessary the tooled surface may be washed with a weak solution of acid and then with an alkali solution to neutralize the effect of the acid.

If a very smooth surface is desired, a veneer of mortar is sometimes placed between the main body of the concrete and the forms. This mortar facing is usually composed of 1 part "ATLAS" Portland Cement to 2 or 3 parts sand and may be applied in several ways. Perhaps the cheapest and easiest method is to trowel a layer of mortar an inch in thickness against the face of the forms and immediately deposit the concrete against it, thus causing the two parts to become thoroughly united. Another method is to hold the concrete away from the forms about 1 inch by means of sheet iron plates while the mortar is being placed between the plates and the forms.

A granolithic finish is given the exposed surfaces of bridges in Philadelphia by applying a 1-inch layer composed of 1 part cement to 2 parts sand to 3 parts broken stone to the inner surface of the forms slightly in advance of the concrete body. After 24 or 48 hours the forms on the faces of the bridge are removed and the concrete surface is immediately rubbed, using a wood block with sand and water and then washing with clean water.

Plastering on concrete surfaces exposed to the weather should be avoided as the plaster is sure to peel off and leave the surface in an unsightly condition unless extraordinary precautions are taken. If plastering is unavoidable the forms must be wet instead of greased. The surface of the concrete should be picked or bush hammered to make it rough, thoroughly wet and then covered with a thin coat of neat cement paste upon which the plaster must be applied in as thin a layer as possible and before the neat cement paste has set.

COST.

There are so many variable items in bridge building that to give accurate figures regarding costs is practically impossible. Frequently the cost is given for a bridge based on a cubic yard of concrete as a unit, while in other cases

the cost per horizontal square foot of roadway surface is taken as a unit. In a paper read by Mr. Henry H. Quimby before the National Association of Cement Users in Cleveland, Jan. 11-16, 1909, he states that the average cost per cubic yard of 18 concrete bridges recently built in Philadelphia was $9.75, with a minimum of $6.50 and a maximum of $11.25 per cubic yard. Basing the cost on a horizontal area equal to the clear span times the width, he gives as an average cost for these bridges $6.50 per square foot, with a range of from $3.11 to $9.74 per square foot. These figures include all the concrete in the arches and abutments.

The cost of the O'Connor Street reinforced concrete skew arch bridge in Ottawa*, Canada, was $8.02 per cubic yard as an average cost for the total of 620 cubic yards including some plain and some reinforced concrete. The cost of the reinforced concrete was $9.80 per cubic yard. This bridge has a span of 20 feet; a length of 46 feet; thickness at crown 18 inches; a rise of 4 feet 10 inches.

The cost of two concrete arches, one of 50-foot and the other of 44-foot span, built by the Pennsylvania State Highway Department in 1907 is given by Mr. G. A. Flink† as $7.50 per cubic yard for the 44-foot span which contains 243 cubic yards of concrete, and $9.50 per cubic yard for the 50-foot span containing 268 cubic yards. The 50-foot span has a rise of 6 feet 9 inches, which is quite small for a bridge of this length.

*The Concrete Review, Vol. 3, Nov. 1, 1908, p. 23.
†Good Roads Magazine, April, 1908, p. 111.

CHAPTER VIII.

RETAINING WALLS.

Retaining walls are frequently required to hold back an adjoining mass of earth from sliding upon a highway or for supporting the lower side of a highway on a side hill. In fact, where the highway is cut in the side of a hill it may be necessary to use a retaining wall on the up-hill as well as the down-hill side of the road. Walls are also necessary in many cases where an embankment is confined to a limited width as, for instance, where the highway is carried up to and over a railroad on an inclined embankment which is confined on either side of the roadway by a wall running parallel with the roadway.

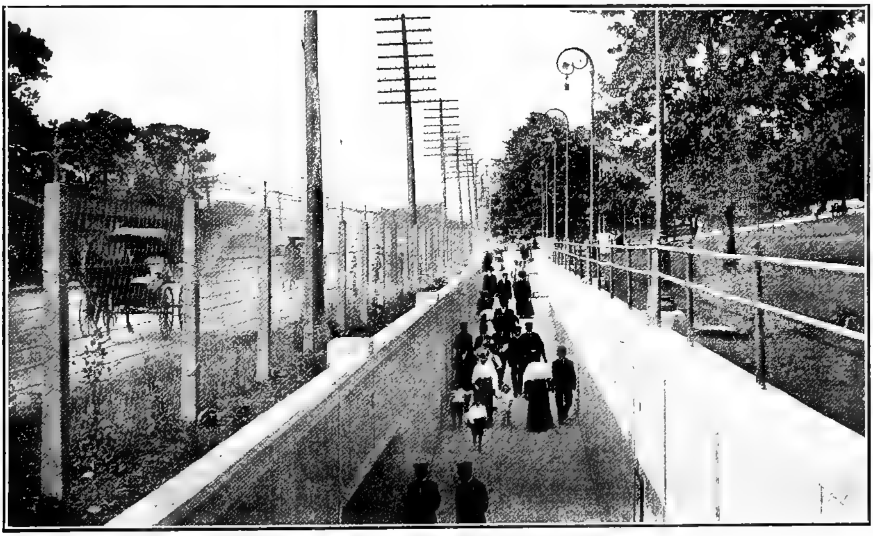


FIG. 58.—RETAINING WALLS AT DELLWOOD PARK, JOLIET, ILL.

Fig. 58 illustrates a use of retaining walls which is quite common. The two walls shown hold back the earth on either side of an inclined passage way leading to the subway entrance in Dellwood Park, near Joliet, Illinois. In the left of the picture is a highway and on the right the park. These walls were built of concrete made of "ATLAS" Portland Cement.

Retaining walls are needed in many places in addition to the uses already cited.

Concrete retaining walls are built either with or without steel reinforcement and they have come into prominence because they are more economical than the stone masonry walls so universally used until a few years ago. Concrete has already demonstrated its usefulness as a material for wall construction, not only because of its low first cost, but also because no maintenance is necessary. A stone retaining wall must be pointed from time to time to keep the joints closed or the masonry will soon be disintegrated by frost. Concrete walls have practically no joints and hence no maintenance charges.

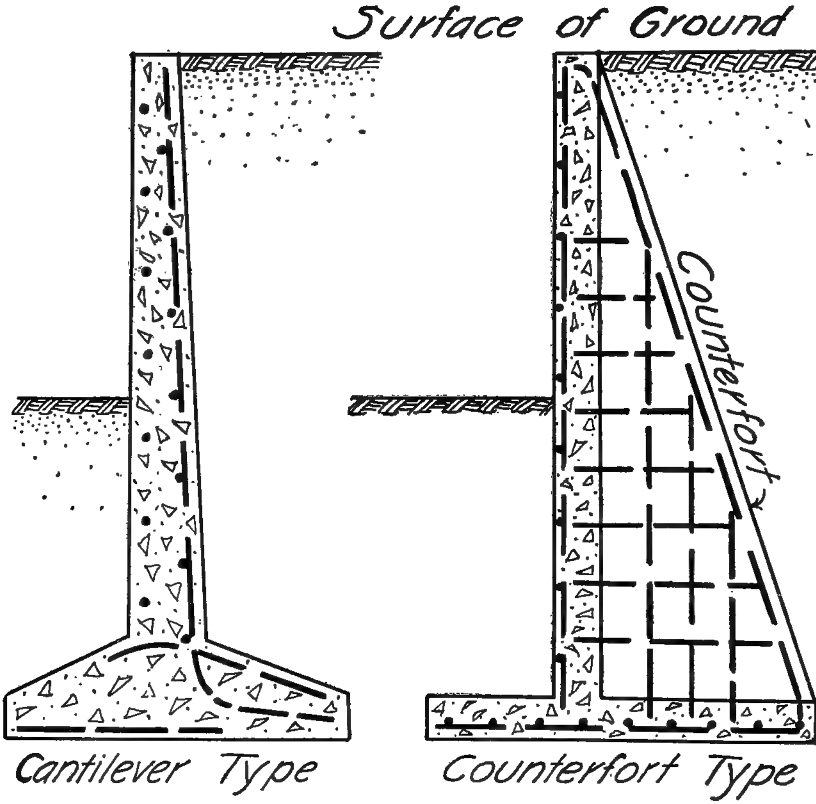


FIG. 59.—TYPES OF REINFORCED CONCRETE RETAINING WALLS

KINDS OF RETAINING WALLS.

Retaining walls are built in the form of thin reinforced concrete walls or as gravity walls of plain concrete containing little or no steel reinforcement.

Gravity walls are designed to withstand the earth pressure behind them by

being made sufficiently heavy to prevent sliding or overturning. They do not utilize the weight of the earth behind them to add to their strength.

Reinforced concrete walls, however, depend to a considerable extent on the earth sustained to add to their stability. The earth behind the walls presses against it, but at the same time the wall is of such a shape that this earth pressure helps to some extent to prevent sliding or overturning. Reinforced walls can be made much thinner than gravity walls and for this reason reinforced walls are usually cheaper.

Reinforced walls as usually built consist of a thin vertical wall attached to a horizontal base and braced either by counterforts on the back or by buttresses on the front side. In more recent designs no buttresses or counterforts are used and the wall then is a vertical slab of reinforced concrete attached to a horizontal base.

RETAINING WALLS, BIRMINGHAM, ALA.

Fig. 59 illustrates the two more usual types of reinforced concrete walls, cantilever and counterfort types.

Buttresses projecting out in front of the wall are not often used, for they take up too much space which in many cases must be utilized for other purposes. In addition they give a very unsightly appearance to the face of the wall.

Counterforts are thin walls running back into the earth behind and serve to

brace the main vertical wall. They are quite frequently used, but the inverted T-shaped cantilever type is so much more easily and cheaply constructed that it should be used unless the wall is at least 18 feet high above ground, in which case the counterfort type may be more economical. Counterforts rest on and are connected to the horizontal base of the wall, and, being reinforced with steel bars, they really act as ties on the back of the wall.

GRAVITY RETAINING WALLS.

With a gravity type of construction, the weight of the wall is relied upon

BEAM BRIDGE ON PRIVATE ESTATE, REDLANDS, CAL.

to sustain the earth pressure and the wall must not only be of sufficient weight but also must have the proper shape.

In the construction of retaining walls of any shape or kind, care must be taken to get good foundations. If the material under the wall is compact sand or gravel, there should be no trouble with the foundation. In some cases, where it is necessary to build a wall on rather soft ground, the sub-soil must be thoroughly drained and in addition it must be compacted by ramming sand or gravel or stone into it. Where the soil is very soft, piles are required to sustain the weight of the wall with the earth pressure behind it. In building walls upon rock which has an inclined surface, this surface must be made horizontal, stepped, or roughened by blasting to prevent the wall from sliding down the

inclined rock surface. Several large retaining walls have failed because this was not regarded. By taking the precautions just mentioned no trouble will be experienced.

Gravity walls are usually made with a coping on top of the main body of the wall. The front or exposed face of the wall is sometimes made vertical and is sometimes given a batter, that is slightly inclined, and the back side of the gravity wall is either sloped or stepped so that the base of the wall is thicker than the top. A slight batter on the face adds to the appearance of the construction, but too large a batter makes the wall look as if it were leaning backwards. For low walls, say those under 12 or 15 feet in height, the face may be made vertical, although a batter of ½ inch per foot while not absolutely necessary is desirable. In heavy construction this batter is sometimes exceeded, but should never be more than 1½ inches per foot.

COPINGS.

The coping for a gravity wall should overhang the front surface of the wall 2 or 3 inches and should be from 12 to 18 inches deep, depending on the height of the wall. For heights of less than 15 feet a coping 12 inches deep should be used, while for walls of greater heights the coping should be 15 to 18 inches deep.

The top surface of the coping should be sloped backward so that dirt will not be washed towards the front edge of the coping and thus will not drop on the front face of the wall and discolor it. The back edge of the top surface should be ¼ inch below the front edge. The front surface of the coping should be vertical and the back is sometimes, though not always, made so. The two upper corners and the front lower corner should be beveled off so that there will be no sharp corners of concrete exposed. This beveling can be best done by nailing in the forms strips of molding having triangular cross sections.

Copings may be laid on top of the wall after the concrete in the wall is hardened or they may be laid at the same time as the body of the wall. The top and front surface of the coping to a depth of 2 inches may be made of a mortar of 1 part "ATLAS" Portland cement and 2 parts clean sand laid between the forms and the inner body of the concrete. In no case should the mortar be plastered on the concrete after the latter has hardened. The upper surface of the coping should be "floated' or finished in the same manner as is the wearing surface of side walls.

Copings should be laid with vertical joints to match the vertical joints in the body of the retaining wall.

FORMS FOR GRAVITY WALLS.

In Fig. 60 is shown a good arrangement for the construction of forms for a gravity wall and a movable form* for building the coping in sections 12 feet long is likewise shown in the same figure.

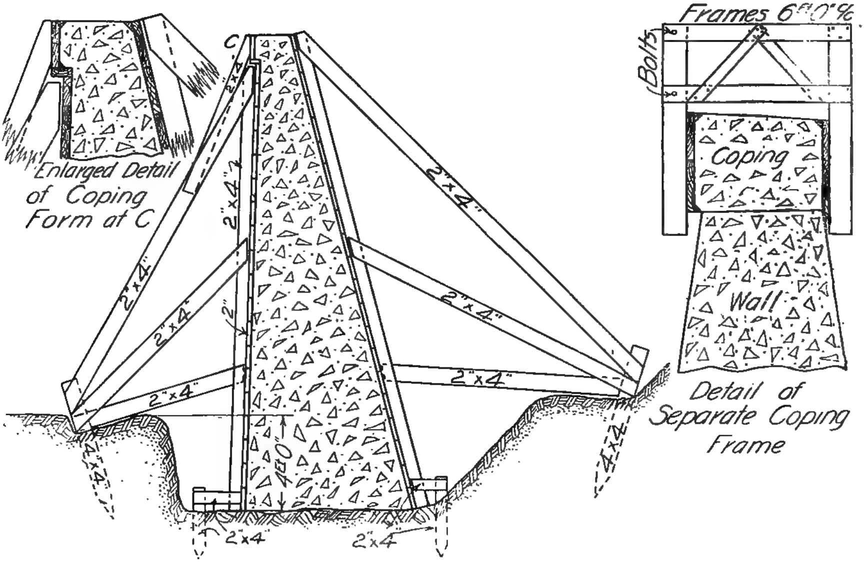


FIG. 60.—FORMS FOR GRAVITY RETAINING WALL

The forms for the wall consist of sheeting made of 1½ or 2-inch lumber braced by 2 by 4-inch studs and 2 by 4-inch inclined struts spiked to a post driven in the ground. The front and back forms are separated by means of 2 by 4-inch braces or by ½-inch bolts running through both of them and also through a piece of 1 or 1½-inch pipe between them, these pipes serving as spacers for the two forms as well. Wires are sometimes used in place of the bolts, but they are apt to stretch or break and bolts are better.

In placing concrete in the forms, care must be taken to avoid any longitudinal joints on the front face of the wall. To this end the wall should be divided into short sections such that the work in one section can be completed without leaving any horizontal joints. Of course in such an arrangement the forms have to be planked up at the outer end of the section, these end boards being removed when the adjoining section is begun.

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*"Engineering News," Vol. L., July 9, 1903, p. 37.

The movable form shown in Fig. 60 is useful where the coping is built after the body of the wall. These forms are made in sections 12 feet in length with 3 of the bracing frames, one at each end and one in the middle of the 12-foot section. They are held in place on top of the wall and the coping concrete is deposited within the form and after the concrete has set the bolts at the points shown are removed so that the forms can be taken off.

DIMENSIONS OF GRAVITY WALLS.

The accompanying table shows dimensions and quantities of concrete for gravity walls shown in Fig. 60, with heights varying from 6 feet to 20 feet, the heights being the difference in elevation between the upper and lower levels of the earth.

DIMENSIONS AND QUANTITIES OF GRAVITY RETAINING WALLS

Height Above Ground Level, Feet	Width of Base	Total Height Feet	Batter on Face Inches	Cubic Yds Concrete in Wall 1 Foot Long
6	2 ft 3 in.	10	4 ½	0 64
8	3 " 0 "	12	5 ½	0.92
10	3 " 9 "	14	6 ½	1.26
12	4 " 6 "	16	7 ½	1.65
14	5 " 3 "	18	8 ½	2.10
16	6 " 0 "	20	9 ½	2.61
18	6 " 9 "	22	10 ½	3.17
20	7 " 6 "	24	11 ½	3.78

The bottom of the wall should in all cases go well below the frost line Four feet has been taken in this case, though of course this will vary with different localities. Four feet, however, is usually enough, even in the coldest climates. The coping is shown 12 inches high and 18 inches wide on top and the top surface should have at least a ¼-inch slope towards the back.

The width of the base must of course be made larger as the height of the wall increases. For highway work where the upper surface of the ground is horizontal and level with the top of the wall it is customary to make the base ⅜ of the height of the wall, the height being taken as the distance between the upper and lower levels of the ground, thus: if the height of the wall is 20 feet the base would be ⅜ of 20, that is 7½ feet. The batter on the front face is ½ inch per foot of vertical distance under the coping, that is, ½ times 23 or 11½ inches. In this case the amount in 1 foot length of wall is 3.78 cubic yards.

Where the earth to be sustained is rather wet and slopes up from the top of the wall instead of being horizontal, the thickness of the base should be ½ of the height of the wall.

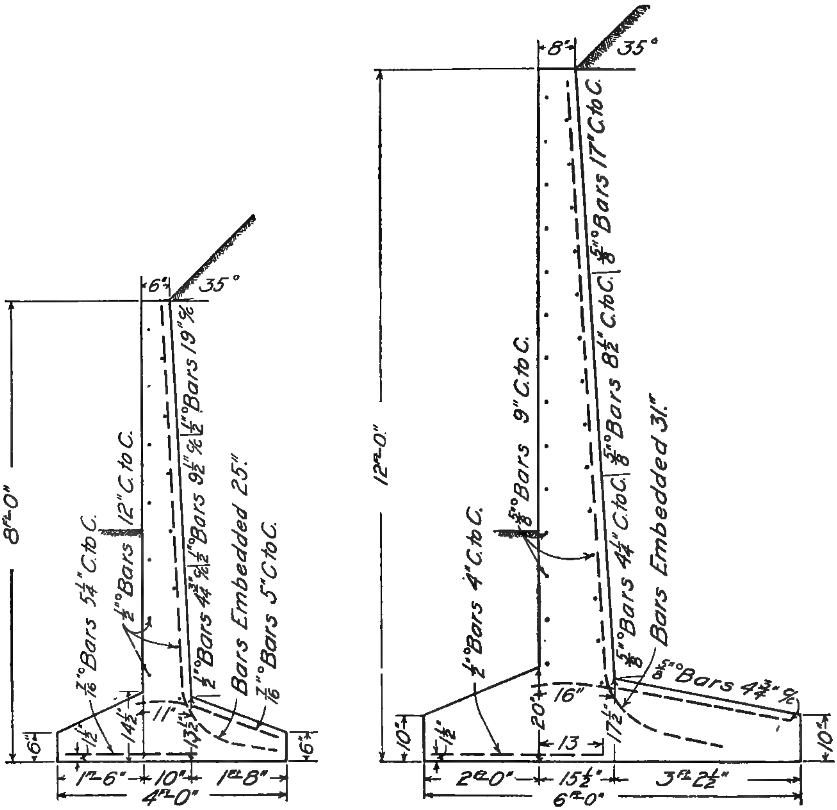
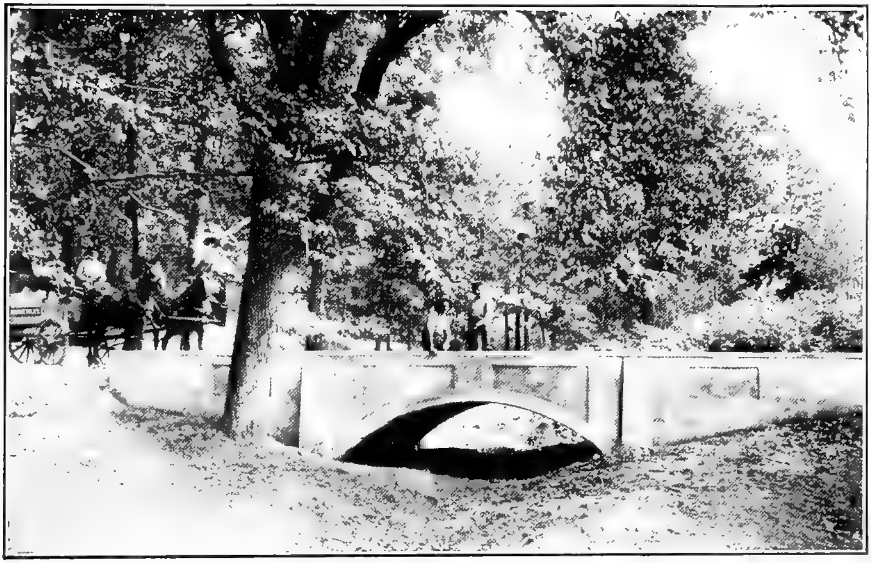


FIG. 61.—SECTIONS FOR REINFORCED RETAINING WALLS.

REINFORCED RETAINING WALLS.

The cantilever retaining walls shown in Fig. 61 consist of a vertical slab of reinforced concrete attached to a reinforced concrete base, the whole section being really an inverted T. The figure shows designs for 2 walls, one for a total height of 8 feet, the other 12 feet. In severe climates the bottom of these walls should be placed 4 feet below the surface of the ground in front of them, thus making the visible height of the finished wall 4 feet and 6 feet respectively. Maximum pressure on soil from these walls is 2 tons per sq. ft.

Great care must be taken to place the steel reinforcement in the exact positions called for by the drawing. In each wall the reinforcement consists of 5 sets of reinforcing bars. In the base of the 12-foot wall there is one set of horizontal half-inch round bars spaced 4 inches apart and $1\frac{1}{2}$ inches above the lower edge of the base. Near the upper surface of the base there is a set of $\frac{5}{8}$-inch round rods spaced $4\frac{3}{4}$ inches apart and slightly inclined as shown in the drawing. In the vertical parts of the wall there are two sets of $\frac{5}{8}$-inch round horizontal rods, one set near the front face and one near the rear face of the wall. Also in the vertical part there is a set of $\frac{5}{8}$-inch round vertical rods



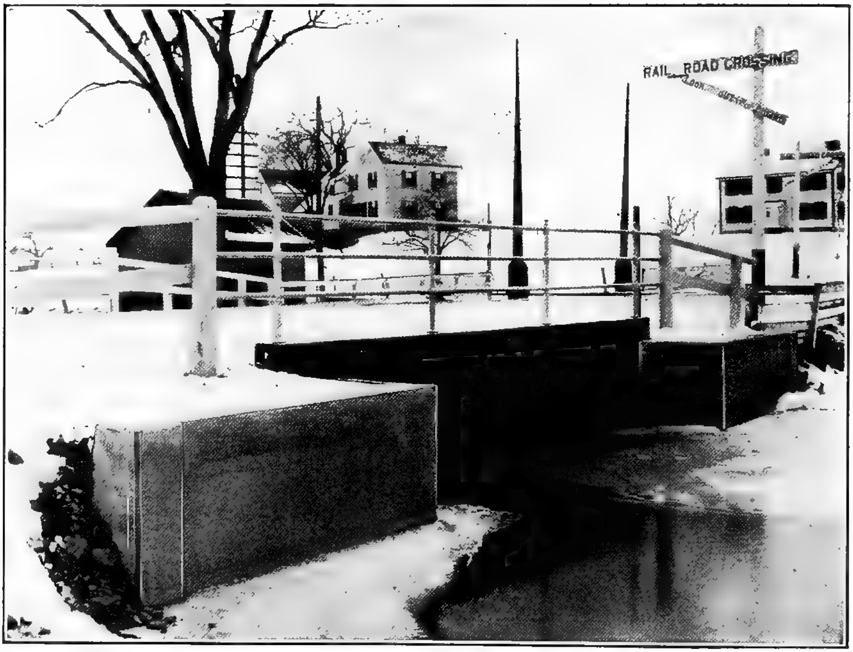
ARCH IN PHILLIPS PARK, AURORA, ILL.

near the back of the wall. These vertical rods must be imbedded in the base as shown. In this set of vertical rods every fifth rod should extend from the bottom to the top of the wall, these rods being 17 inches apart. Then midway between each pair of these long rods a shorter rod extends from the bottom of the wall 2/3 of the way to the top, making the rods in the middle third of the height $8\frac{1}{2}$ inches apart. In the lower third of the height there are in addition to the rods mentioned short rods running from the base up 1/3 of the height of the wall, thus making the rods in this lower third $4\frac{1}{4}$ inches c. to c.

Although $\frac{5}{8}$-inch round rods are shown in the figure, other bars having the same cross sectional area can be used instead.

PROPORTIONS OF CONCRETE.

For gravity walls similar to those described in this chapter for the body of the wall and for the body of the coping the concrete should be mixed 1 part "ATLAS' Portland Cement, 3 parts sand and 6 parts broken stone or gravel. For the upper and front surfaces of the coping a 2-inch veneer of mortar mixed 1 part "ATLAS" Portland Cement and 2 parts sand may be used, built on a part of the coping at the same time that the concrete is placed. For a gravity wall having a height of more than 12 feet "one-man" stones may be



BEAM BRIDGE, SUDBURY, MASS.

imbedded in the concrete as indicated in Chapter I under the head of Rubble Concrete.

For reinforced concrete walls similar to those described in this chapter concrete should be mixed 1 part "ATLAS" Portland Cement, 2½ parts sand and 5 parts broken stone or gravel.

In depositing the concrete against the forms, care must be taken to prevent the larger stones from collecting in pockets against the forms and thus making voids which will show when the forms are removed.

EXPANSION JOINTS.

When concrete is subjected to changes in temperature it will expand or contract. Therefore, in long retaining walls vertical cracks will form in the concrete unless the wall is either reinforced with steel or vertical joints are made at frequent intervals. For plain concrete walls vertical joints should be left at intervals not exceeding 30 feet; these joints allowing the sections of concrete to expand or contract without forming unsightly cracks in the face of the wall. While 30 feet is the maximum distance between expansion joints in plain concrete walls, 20 feet is the proper distance, and walls provided with joints 20 feet apart will not crack. Frequently these joints are run straight through the wall from front to back. It is better, however, to have the two adjacent sections of the wall tongued-and-grooved or V-shaped in plan.

DRAINAGE.

Unless provision is made for removing the water, it will in most cases collect behind the retaining wall and considerably increase the pressure on the back of the wall. With clayey soils or other material of similar nature, some provision must be made for removing this water by drainage. If the wall is short, a broken stone drain laid lengthwise behind the wall and properly graded so that the water will flow along the back and then away from the wall will serve every purpose. In the case of long walls, drainage holes must be placed through the wall so that the water may pass from the back to the front where it can be drained off. These drainage holes can be made by placing cement or clay tile pipes 3 or 4 inches in diameter in the concrete, sloping downward toward the front of the wall. Wooden forms of 1-inch planks can be used to make a square hole, but the planks are hard to remove after concreting. The outlet in the front face should be 6 inches above the surface of the ground in front of the wall. Two or three barrow loads of cobble stones and gravel should be placed at the upper end where the pipe pierces the back surface of the wall.

In very wet soils loose stones 10 to 15 inches in thickness should be piled up against the back of the wall from the bottom to within 2 feet of the top. This arrangement together with the weep holes just described will afford perfect drainage even in very wet material.

Weep holes should be placed from 10 to 20 feet apart lengthwise of the wall, depending on the nature of the soil. They should be placed 10 feet apart in wet ground.

CHAPTER IX.

MISCELLANEOUS.

FENCE POSTS.

Reinforced concrete fence posts are better than wooden ones because they will not decay, are more uniform in size and shape, and in the long run are cheaper. Fence posts of wood are cheaper in first cost than those made of concrete, but ordinary wooden posts decay in a comparatively short time while concrete construction lasts indefinitely. Cast iron posts last very well, but their cost prohibits their use except in a few cases. Concrete posts properly reinforced with steel rods possess the necessary strength and durability and at the same time may be obtained in any locality at a reasonable cost.

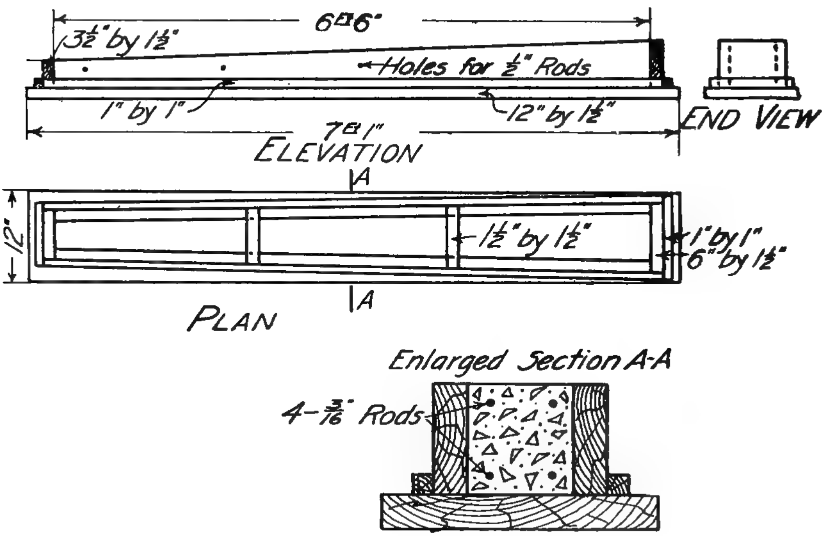


FIG. 62.—FORMS FOR CONCRETE FENCE POSTS.

Fence posts for farms and for division fences in city suburbs should generally be 7 feet long, 6 inches square at the lower and 4 inches square at the upper end. These posts are usually made to support wire fences.

For fences adjoining streets in towns the posts should be from 5 to 6 feet in length with ends the same size as for farm posts. These posts carry wire

fences or wooden fences. If a wooden fence is supported by concrete posts the street side of the posts should be set vertical, the lower wooden stringer of the fence being bolted to the front vertical face of the post and the upper stringer bolted on top of the post.

A form for making an individual post is shown in Fig. 62 and consists of a base board 1½ inches thick and 12 inches wide. Upon this are set two beveled pieces of 2-inch lumber 6 inches wide at one end and 4 inches wide at the other. The two side boards, connected with 2 or 3 cross braces on top, are set against, but not nailed to, the two small strips, the latter being nailed to the base board. The blocks at the ends are nailed in place.

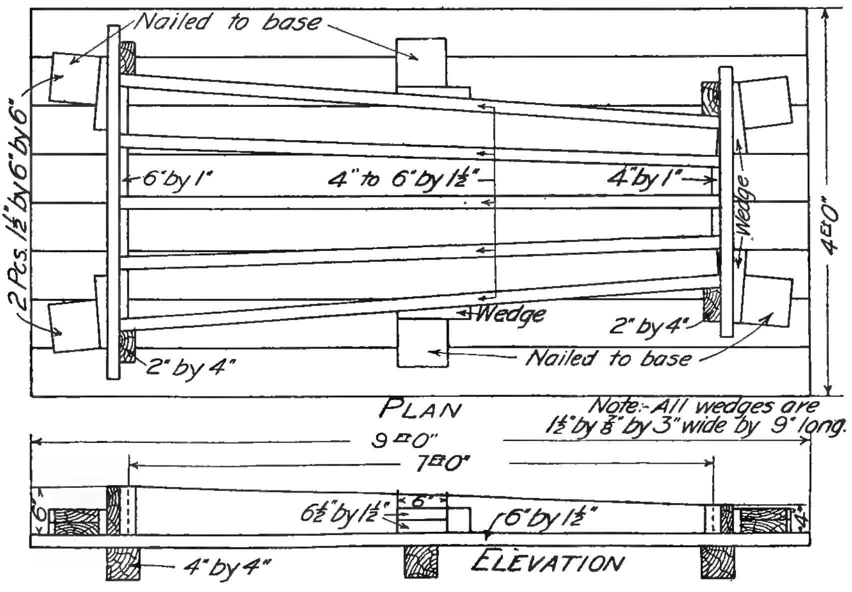


FIG. 63.—MULTIPLE FORM FOR CONCRETE FENCE POSTS.

Short pieces of ½-inch greased round rods should be placed through the side boards before the concrete is placed in the forms and allowed to remain four or five hours till the concrete is hardened enough so that they can be pulled out. The fence wires can be run through these holes or can be run in front of the post and tied to the same with No. 12 or 14 galvanized wire. These holes for fence wires do not decrease the strength of the post and afford a better method of attachment than staples placed in the front surface of the post. If staples are used they must be galvanized.

With the form in place, concrete, made one part "ATLAS" Portland Cement, two parts clean coarse sand, and four parts broken stone or screened gravel of about one inch diameter particles, should be placed in the form and tamped to a thickness of one inch. Then two pieces of wire about 3/16 inch in diameter and 6½ feet long are placed on the layer of concrete, each one inch from the side forms. Another layer of concrete must then be tamped on the first layer until the concrete is within one inch of the top edge of the side forms and two more wires like the first ones then laid and the forms filled with concrete. After the concrete is tamped and smoothed off on the upper surface, the post is set aside and allowed to lie ten or twelve hours before the side forms are removed. The base board must be left in place ten days during which time the post must be sprinkled daily and must not be disturbed. After this time the posts should be allowed to harden for four weeks more before being used.

Fig. 63 shows a mold for casting four posts at a time. The boards separating the posts are slipped in between cleats at each end and are either screwed to the end pieces or held in place by tightening up the wedges at the ends. Wedges bearing against blocks nailed to the base board prevent the side boards from spreading. Staples pressed in the upper face of the concrete before the concrete sets afford an easy connection for the fence wires.

Forms should be made of dressed lumber and should be oiled or greased with soft soap before using.

Fence posts such as here described should cost from thirty to fifty cents each.

Corner posts must be larger than the side posts, 10 by 10 inches at the base and 10 by 10 inches at the top, and 9 feet long being good dimensions. Use four ⅜-inch round rods for reinforcement of 3/16-inch.

CONCRETE FENCE POSTS AT DELLWOOD PARK.

In Fig. 64 are shown some concrete fence posts around Dellwood Park, four miles from Joliet, Ill. This fence* encloses a tract of land approximately 1,320 feet wide by 2,200 feet long and has 1,500 concrete posts varying in length from 7 to 9 feet. At the top the posts are 4 inches square and at the bottom they are 4 by 6 inches in cross section. The concrete was made one part "ATLAS" Portland Cement and one part stone screenings passing a ¼-inch screen. The reinforcement consists of four rods, one in each corner.

The forms used were similar to the single form shown in Fig. 62 and were left on the posts twenty-four hours, the side boards being removed after this period. The posts were then left for an additional twenty-four hours lying

*Engineering Record, Vol. 55, March 23, 1907, page 377.

on the base boards after which the bases together with the post were moved to a platform where they remained a week. They were then laid out to harden till used, being kept wet for the first three weeks after they were made. Two men, each paid $2 per day, could make about forty posts in one day. The cement cost $2 per barrel, the reinforcement 3½ cents per pound and the screenings 75 cents per cubic yard. The posts, 9 feet long, cost 65 cents each, a rather high cost because of the design and the richness of the proportions. Posts at angles of the fence were heavier than the others and were braced.

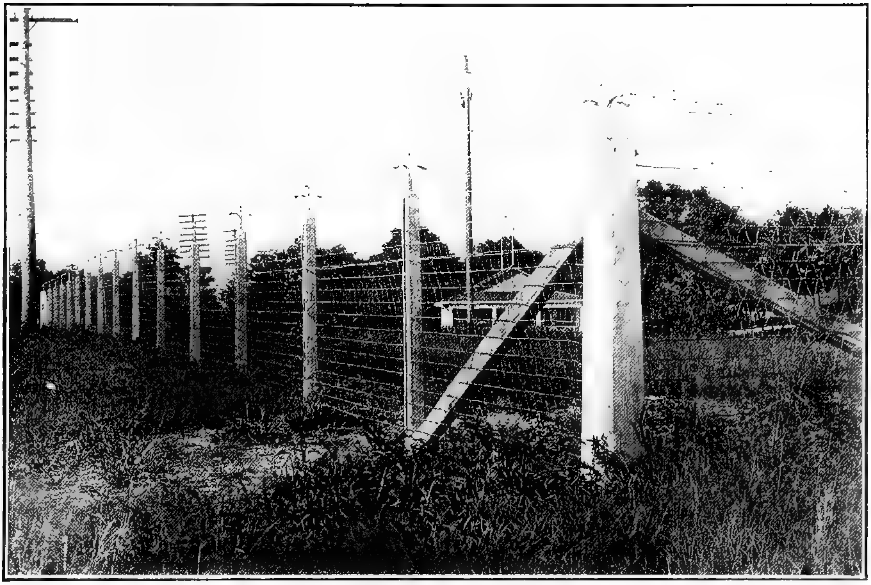


FIG. 64.—CONCRETE POSTS AT DELLWOOD PARK, JOLIET, ILL.

HITCHING POSTS.

Concrete hitching posts without reinforcement do not have sufficient strength. They must be reinforced with a ⅜-inch diameter rod imbedded in each corner. Hitching posts should be set at least 2½ feet in the ground if they are surrounded by a concrete sidewalk. If set in earth without the surrounding walk they should be placed 3 feet in the ground. The outer surface must be at least 6 inches, or still better, 8 inches from the edge of the curb.

Posts similar to that shown at the left side of Fig. 65 are made in the same

manner as fence posts except that there is a 2-inch ring attached to a staple in the top.

The post shown in the right half of Fig. 65 is neat but is more difficult to make than the plain post. The depressed surfaces on the sides are one-half inch deep and are best formed by nailing one-half-inch wooden pieces to the inside of the forms. Tamp the concrete into the corners of the molds well and after the forms are removed give the surfaces of the posts a coating of cement mixed with water, applied with a brush.

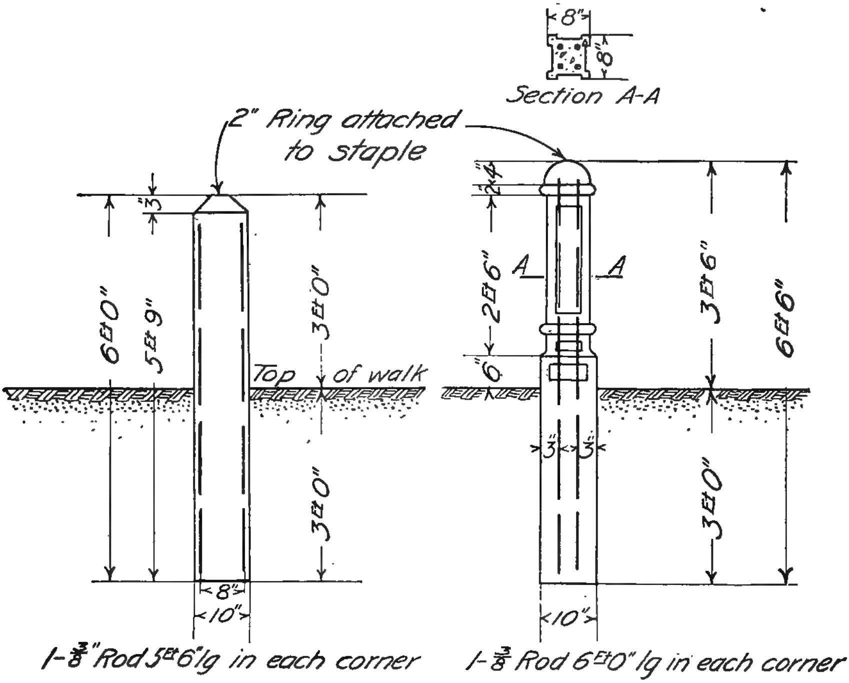


FIG. 65.—CONCRETE HITCHING POSTS.

LAMP POSTS.

Concrete is being used for lamp posts to support electric lights in parks and other similar places. These posts are usually about 20 to 24 feet in length and are set 5 or 6 feet into the ground. They should be 6 or 8 inches in diameter at the bottom and 4 or 5 inches at the top, the larger diameters being required for the highest posts. A piece of 1-inch gas pipe is placed in the center of the post throughout its length to carry the wires from the lamp to the bottom of the post where the wires then connect with the underground

electric system. The lamp can be set directly on top of the post or it can be suspended from the outer end of a curved pipe which is connected to the pipe passing down through the post. The methods of construction are similar to those used in making fence posts.

One rod one-half inch in diameter in each corner of a square post is sufficient for reinforcement. A square post with beveled edges is simpler to make than a round post, but is not quite so neat in appearance.

BRIDGE AND DRINKING FOUNTAIN, LINCOLN PARK, CHICAGO, ILL

DRINKING FOUNTAINS.

Drinking fountains of concrete are giving good satisfaction in parks even where the climate is severe. These fountains are generally made with a circular base about 3 feet in diameter and a circular stem and bowl on top; the stem gradually diminishing in diameter from the base and then enlarging into the bowl which is from 3½ to 4 feet in diameter.

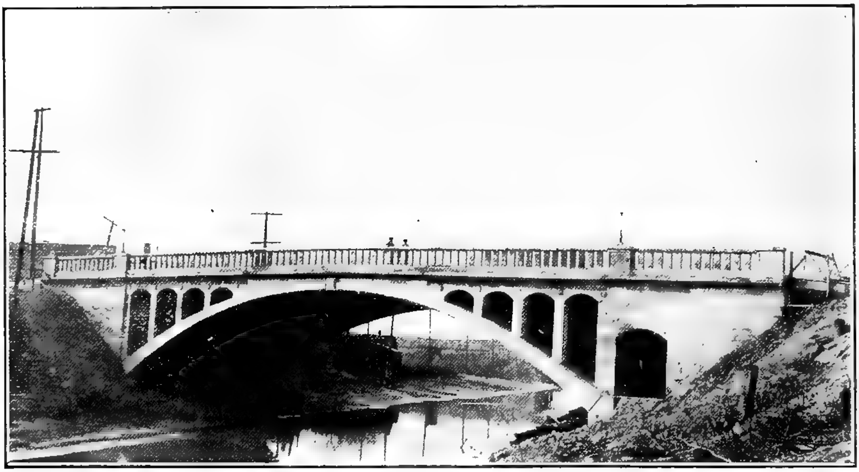
Reinforcement must be used in fountains to give them sufficient strength to withstand shocks. Wire mesh of any kind bent to shape and imbedded in the concrete is all that is necessary.

The concrete must be mixed quite wet, about the consistency of thick cream and in the proportions of 1 part "ATLAS" Portland Cement, 1½ parts

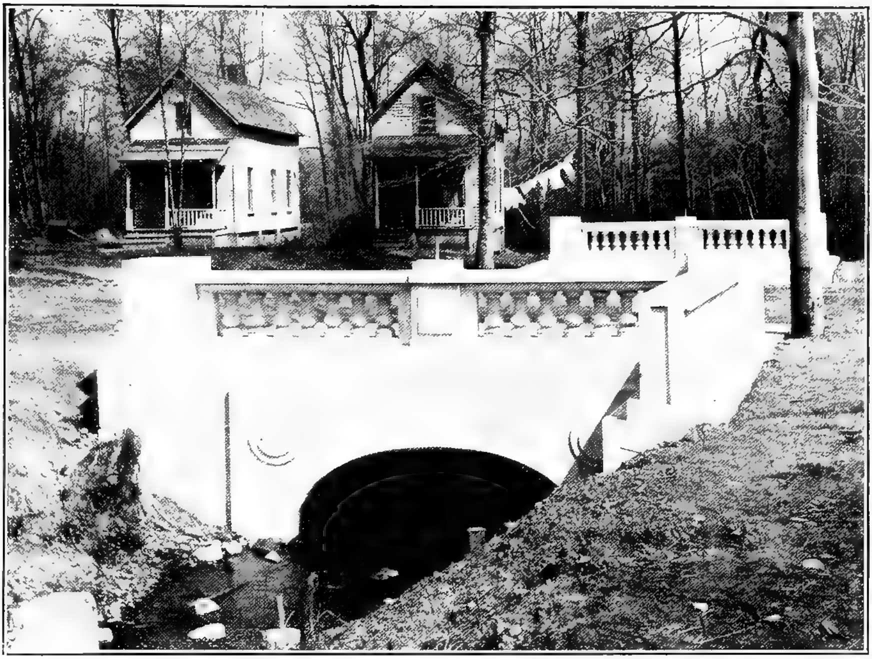
clean, coarse sand, and 3 parts broken stone or screened gravel of about 1 inch diameter.

The bowl must be cast at one operation and as quickly as possible so that it will be water tight.

Good drinking fountains of this kind have been built for $12 with $5 for the setting.



BRIDGE WITH OPEN SPANDRELS, CHICAGO, ILL.



BRIDGE AT HAWORTH, N. J.

PARKWAY BRIDGE. MEDFORD, MASS.

WALNUT LANE BRIDGE, PHILADELPHIA.

CONCRETE
IN
RAILROAD
CONSTRUCTION

A TREATISE ON CONCRETE
FOR
RAILROAD ENGINEERS AND CONTRACTORS

PRICE, $1.00

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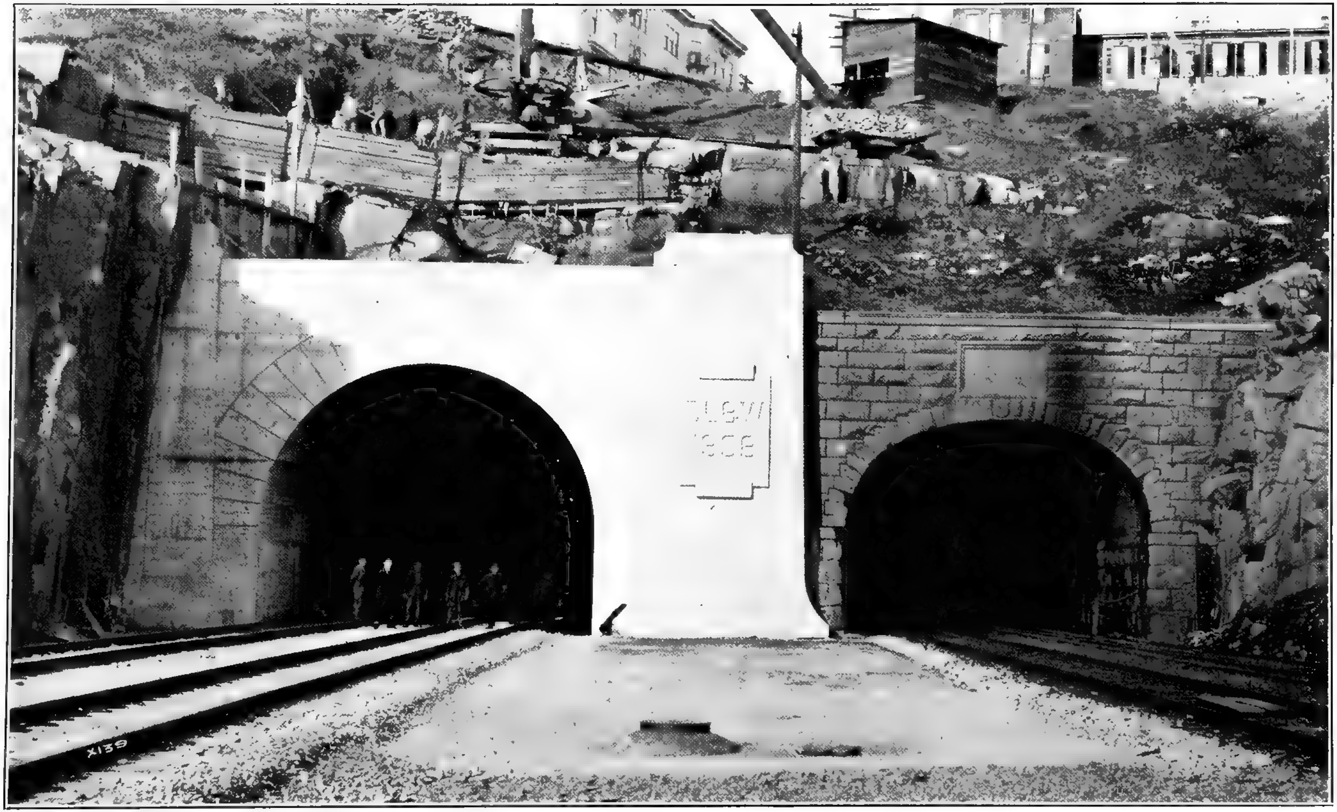

ENTRANCE TO OLD AND NEW BERGEN HILL TUNNELS

INTRODUCTION.

Economy in railroad construction demands permanent structures. Materials must be used therefore which as far as possible are proof against the deteriorating and destructive influences of the elements and of vibration, so as to resist corrosion, decay and fire, and the gradual weakening due to continual, severe and constantly growing service. At the same time the materials must possess requisite strength for present and future traffic combined with cheapness and facility of construction.

The advent of reinforced concrete, possessing as it undoubtedly does in a marked degree all these qualities combined with a wide range of possible uses and versatility of design, has been of the greatest importance to railroad engineers.

To illustrate the best of present day practice, The Atlas Portland Cement Company takes this opportunity to present to the railroad world at large a brief treatise on concrete in railroad construction, with a view of giving a comprehensive idea of the diversity of the concrete structures in actual existence on railroad lines throughout the country and of the future possibilities of this material in the field of railroad engineering.

Realizing that the treatment of this subject demanded the attention of an expert authority the work was entrusted to Mr. Sanford E. Thompson, M. Am. Soc. C. E., one of the foremost concrete experts in the country. The Atlas Portland Cement Company, occupying as it does a somewhat unique position among cement manufacturers, with its wide reputation for a thoroughly uniform and standard product, its selection by the United States government to furnish 4,500,000 barrels for use in building the Panama Canal, and its immense production—over 40,000 barrels per day—commends the book to its readers with the hope that it may prove a fitting sequel to the former publications of the company—"Concrete Construction About the Home and on the Farm," "Concrete Cottages," "Concrete Country Residences," "Reinforced Concrete in Factory Construction" and "Concrete in Highway Construction."

THE ATLAS PORTLAND CEMENT COMPANY.

New York, July, 1909.

PREFACE.

In compiling this book it has been the aim of the author and of the publishers to cover as thoroughly as possible the entire field of the uses of concrete in railroad construction. Although it is very fully illustrated, the photographs and drawings are presented not as mere pictures but to illustrate in detail the many points which are continually occurring to the railroad officials and their engineers and designers. With this in view, typical structures of nearly every class are shown, with a short description of the essential features of design and construction of each.

The first chapter contains a brief review of the qualities of concrete in comparison with other materials for railroad construction and this is followed by a chapter on design and construction designed to serve as a guide to the intelligent use of concrete. In the descriptive portion of the book, which embodies fifteen chapters, the following subjects have been treated: Bridges, Culverts, Piers and Abutments, Retaining Walls, Stations, Train Sheds, Platforms, Coal and Sand Stations, Coal Trestles, Ash Handling Plants, Roundhouses, Turntable Pits, Signal Towers, Water Tank Supports, Bumping Posts, Power Stations, Shops, Warehouses, Grain Elevators, Storage Reservoirs, Docks, Tunnels and Tunnel Lining, Cross Ties and Road Beds, Telegraph Poles, Transmission Towers, Posts and Fences. A number of miscellaneous illustrations of general interest are shown at the end of the book.

All illustrations have been prepared especially for this book, the half-tones being made from original photographs while the drawings were reproduced in the office of the author from the original plans furnished by the chief engineers of the various railroads.

In certain cases, where none of the designs of existing structures were sufficiently representative in character, special designs have been prepared.

The descriptive matter and drawings have been compiled under the immediate direction of Mr. Chester S. Allen of the author's engineering staff. The author also acknowledges the assistance of Prof. Frank P. McKibben in reviewing the original designs.

The text and the drawings of each structure have been referred to the officials of the railroad for their approval.

The Atlas Portland Cement Company, and the undersigned, desire to express their appreciation of the courtesies extended by the engineers of the various railroads and by the contracting companies who have so kindly furnished plans and data for incorporation into the descriptive chapters of this book.

SANFORD E. THOMPSON,

1909. Newton Highlands, Mass.

CHAPTER I.

RAILROAD CONSTRUCTION.

While the policy of European railroad engineers always has been to build permanent structures, the necessity in the past of practising the strictest economy in the original building of many of the railroads of this country has led American engineers to exactly the opposite course, and as a result railroad structures built not many years ago were largely of timber; bridges were of the Howe truss and lattice type, trestles of pile and timber construction, and stations, roundhouses and freight sheds veritable wooden fire traps.

The increasing importance with the attendant increase of incomes of the railroads and the need for more permanent structures coupled with the improvements in iron manufacture resulted in the substitution of wrought iron structures in place of the wood, and this material in turn was replaced by steel. But it was soon found that steel was by no means perfect, since structures built of it required careful inspection and continual repairs and even then rust and gases had such a deteriorating effect that the life of a steel bridge or building would probably be not over 30 or 40 years.

In the past few years concrete has had a marvelous growth, and in railroad construction perhaps more than in any other branch of engineering it has been universally adopted as a building material. Not only is it replacing steel construction, but perhaps still more it has taken the place of stone and brick masonry not only for foundations but also for various structures above ground, such as retaining walls, bridges, coaling stations, signal towers, and in fact many of the smallest details.

COST.

While the cost of concrete construction is invariably higher than wood, it is almost always considerably less than stone masonry and will not greatly, if at all, exceed steel in first cost.

The maintenance costs of a concrete structure are practically neglible and it has been estimated that the elimination of painting costs alone warrants an initial expenditure of from 10 per cent to 15 per cent over the first cost of a steel structure.

SAFETY.

When well designed and properly constructed, a reinforced concrete structure will be safe for all time, since its strength increases with age, the concrete growing harder and the bond with the steel becoming stronger.

In building such a structure, it is of the utmost importance that the plans and specifications should be followed absolutely and that work should be entrusted only to men of undoubted experience in this line of construction.

DURABILITY.

While steel and wooden structures grow weaker from rust and decay a concrete structure as stated above grows stronger with time and its life is measured by ages rather than years. In addition to its natural permanence, such a structure is proof against tornadoes, high-water, fire and earthquakes. A number of concrete buildings in San Francisco withstood the shock of the earthquake, while those around them of terra cotta brick and stone were destroyed.

FREEDOM FROM VIBRATION.

Concrete is especially adapted for railroad construction owing to the fact that its solidity and entire lack of joints render it free from the excessive vibrations often experienced in steel structures. In riding over a structure built of concrete it is particularly pleasing to the passenger to note the absence of the familiar roar and the lurching of the train which is so often endured in crossing a steel bridge. Only where there is direct contact, as in ties, is there danger of the jar disintegrating the concrete. In such cases either cushions of wood or earth should be provided to deaden the shock, or the concrete should be placed in large mass.

FIRE RESISTANCE.

In addition to its permanence and strength, concrete is especially suited to the construction of warehouses, terminal buildings, bridges, stations, coal pockets and similar structures on account of its undoubtable fire-resisting qualities. Actual fires and fire tests have demonstrated time and again the ability of reinforced concrete to withstand even extraordinary fires. This is a valuable asset not only for buildings and warehouses, but particularly for structures to be used for the storage of coal, since the railroads of this country

have suffered in the past much inconvenience and expense through the use of inferior bins of timber or steel. The spontaneous combustion to which coal is subject when stored in great quantities not only results in the loss of the coal itself and the damaging of much valuable machinery, but also in the destruction of the bin if it is constructed either of wood or steel.

As a result of the lessons taught by the recent terrible fires along the waterfront of Hoboken, the new piers designed to replace those burned down in the fire of 1904 are to be built entirely of concrete and steel construction.

VERSATILITY OF DESIGN.

Concrete enjoys a wider range of possible use and varieties of design than any known building material. An evidence of its adaptability to the endless variety of uses in railway design is shown by the thirty-five classes of construction described in the text of this book.

WATER-TIGHTNESS.

It was formerly thought necessary to waterproof a structure where it came in contact with ground water. But now by using a proper amount of reinforcement to prevent cracks due to shrinkage from temperature and by properly forming the joints, concrete is used in many cases with no surface waterproofing. In the Philadelphia subway after experimenting with various methods of waterproofing it was decided to depend entirely on the concrete itself, and in the New York subway no waterproofing is now being used above high-water level. Concrete is especially adapted for use in the construction of conduits, dams, tanks, reservoirs and other structures which, to accomplish their purpose, must be essentially water-tight.

ALTERATIONS.

Owing to the difficulty in tearing it down concrete is not suitable for a temporary structure. While radical changes in construction are not readily made, holes may be cut in walls and floors, at greater expense than in wood, but without serious difficulty.

STRENGTHENING OLD MASONRY.

Concrete from its very nature is well adapted for reinforcing or strengthening and protecting old stone masonry which is being disintegrated by the action of the weather.

FOUNDATIONS.

Concrete has been used for foundations in railroad construction for years; in fact, until recently this was practically the only use. With the development of design, reinforcement has been introduced which often saves much material.

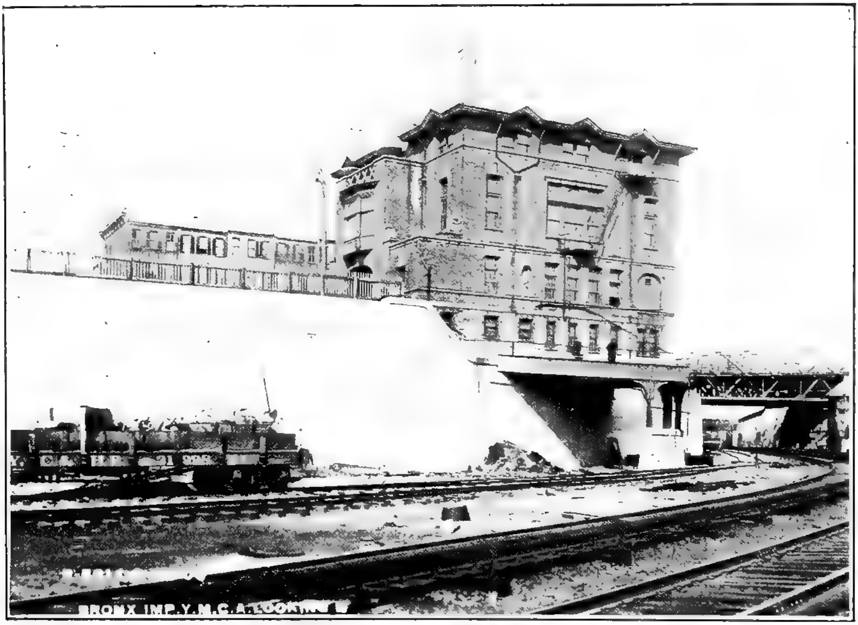

FIG. 1.—RETAINING WALL AND PROTECTION PIER, BRONX IMP., N. Y. C. & H. R R. R.

CHAPTER II.

DESIGN AND CONSTRUCTION.

Although the use of reinforced concrete is comparatively recent, there have been sufficient tests and the theory is far enough developed to design with absolute security not only masonry structures like foundations, bridges, retaining walls, abutments and piers, but structures embodying beams and slabs, such as girders, bridges, coaling stations and power plants.

Numerous tests have been made during the last few years on almost all the details of concrete construction not only at nearly all the universities, but the Structural Materials Testing Laboratories at St. Louis under the direction of the United States Geological Survey has been taking up the subject in a scientific manner.

Besides this experimental work, the use of reinforced concrete is so widespread that practice is rapidly confirming the theoretical demonstrations.

CEMENT.

While brief specifications for cement may be sufficiently comprehensive for work of minor importance, the standard specifications adopted by the American Society for Testing Materials* are generally adopted for important work throughout the country.

SAND.

The selection of sand for use in concrete work is quite as important as that of the cement and it should be carefully tested for all important structures. As a guide for the proper selection of the aggregates the following is quoted from the Progress Report of the Joint Committee on Concrete and Reinforced Concrete, 1909.†

> "a. FINE AGGREGATE consists of sand, crushed stone, or gravel screenings, passing when dry a screen having ¼-inch diameter holes. It should be preferably of silicious material, clean, coarse, free from vegetable loam or other deleterious matter.

---

*These may be obtained by addressing The Atlas Portland Cement Company.

†Affiliated Committees of American Society of Civil Engineers, American Society for Testing Materials, American Railway Engineering and Maintenance of Way Association, Association of American Portland Cement Manufacturers.

"A gradation of the grain from fine to coarse is generally advantageous.

"Mortars composed of one part Portland cement and three parts fine aggregate by weight when made into briquets should show a tensile strength of at least 70 per cent of the strength of 1:3 mortar of the same consistency made with the same cement and standard Ottawa sand."

BROKEN STONE AND GRAVEL.

"b. COARSE AGGREGATE consists of inert material, such as crushed stone, or gravel, which is retained on a screen having ¼-inch diameter holes. The particles should be clean, hard, durable, and free from all deleterious material. Aggregates containing soft, flat or elongated particles should be excluded from important structures. A gradation of size of the particles is generally advantageous.

"The maximum size of the coarse aggregate shall be such that it will not separate from the mortar in laying and will not prevent the concrete from fully surrounding the reinforcement or filling all parts of the forms. Where concrete is used in mass, the size of the coarse aggregate may be such as to pass a 3-inch ring. For reinforced members a size to pass a 1-inch ring, or a smaller size, may be used.

"Cinder concrete is not suitable for reinforced concrete structures, and may be safely used only in mass for very light loads or for fireproofing.

"Where cinder concrete is permissible the cinders used as the coarse aggregate should be composed of hard, clean, vitreous clinker, free from sulphides, unburned coal, or ashes."

Owing to the presence of vegetable loam or other deleterious matter, it is often necessary to wash the aggregates, and the drawing in Fig. 2 shows an apparatus designed by Mr. Allen Hazen and Mr. William H. Ham and used with good success by the contractors, Messrs. Tucker and Vinton.

STEEL.

There is frequently a question as to the use of high or low carbon steel. High carbon steel is very apt to be brittle unless it is made so as to pass severe tests,* when it can be depended upon.

It is generally economical to use ordinary medium steel unless perhaps for temperature reinforcement, when steel with high elastic limit and deformed section is especially good.

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*See Specifications in Taylor & Thompson's "Concrete Plain and Reinforced," Second Edition, 1909. John Wiley & Sons, New York, publishers.

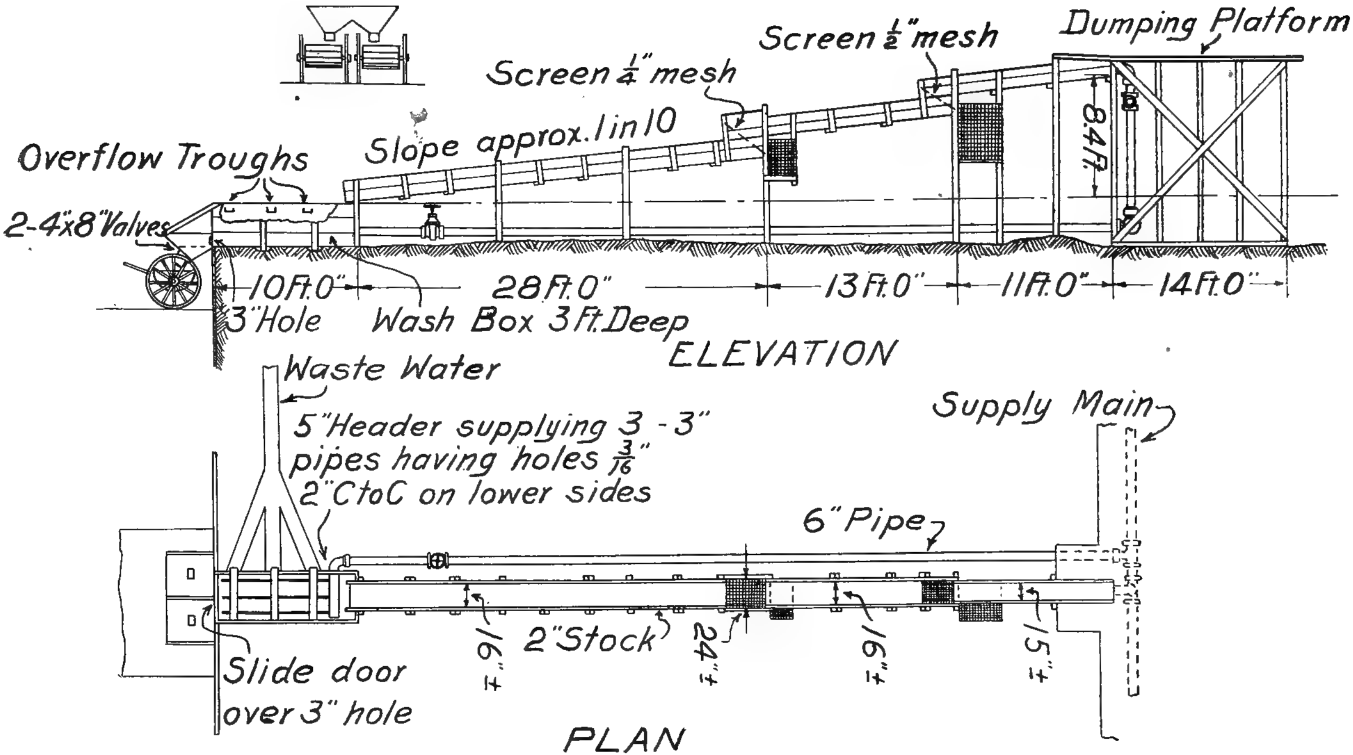

FIG. 2.—SAND AND GRAVEL WASHER, ETC.

For ordinary uses, deformed bars, that is, bars with irregular sections, while satisfactory and in some cases better than ordinary round bars, are usually not absolutely necessary.

PROPORTIONS.

In such a broad field of construction as is found in railroad work, it is impossible to give any general recommendations as to the proper proportions to use, as this depends so much on the structure itself. For any specific structure, the reader is referred to the proportions adopted in the construction of similar structures described in the text.

The standard method for measuring parts is to assume one part as equal to 4 bags of cement, or one barrel. In measuring the sand and stone a barrel is assumed as 3.8 cubic feet. The actual volume of a cement barrel averages about 3.5 cubic feet, but the 3.8 cubic feet has been adopted generally in practice as corresponding to a weight of 100 pounds of cement to the cubic foot, which is that of the cement partially compacted; thus proportions 1:2:4 means one barrel (or 4 bags) Portland cement, 7.6 cubic feet sand measured loose and 15.2 cubic feet of broken stone or gravel measured loose.

MIXING.*

"The ingredients of concrete should be thoroughly mixed to the desired consistency, and the mixing should continue until the cement is uniformly distributed and the mass is uniform in color and homogeneous, since maximum density and therefore greatest strength of a given mixture depends largely on thorough and complete mixing.

"(a) Measuring Ingredients. Methods of measurements of the proportions of the various ingredients, including the water, should be used, which will secure separate uniform measurements at all times.

"(b) Machine Mixing. When the conditions will permit, a machine mixer of a type which insures the uniform proportioning of the materials throughout the mass should be used, since a more thorough and uniform consistency can be thus obtained.

"(c) Hand Mixing. When it is necessary to mix by hand, the mixing should be on a water-tight platform and especial precautions should be taken to turn the materials until they are homogeneous in appearance and color."

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*From Joint Committee's recommendations, see footnote, page 15.

CONSISTENCY.

The required consistency varies with the class of work. Concrete is strongest when not too wet, but of a medium jelly-like consistency. For reinforced concrete it must be softer, so that it can just flow sluggishly around the steel and into the forms. At the same time it should be stiff enough to be conveyed from the mixer to the forms without separation of the coarse aggregate from the mortar.

PLACING.*

"(a) Methods. Concrete after the addition of water to the mix should be handled rapidly, and in as small masses as practicable from the place of mixing to the place of final deposit, and under no circumstances should concrete be used that has partially set before final placing. A slow setting cement should be used when a long time is liable to occur between mixing and final placing.

"The concrete should be deposited in such a manner as will permit the most thorough compacting, such as can be obtained by working with a straight shovel or slicing tool kept moving up and down until all the ingredients have settled in their proper place by gravity and the surplus water forced to the surface.

"In depositing the concrete under water, special care should be exercised to prevent the cement from being floated away, and to prevent the formation of laitance which hardens very slowly and forms a poor surface on which to deposit fresh concrete. Laitance is formed in both still and running water, and should be removed before placing fresh concrete.

"Before placing the concrete care should be taken to see that the forms are substantial and thoroughly wetted and the space to be occupied by the concrete free from debris. When the placing of the concrete is suspended, all necessary grooves for joining future work should be made before the concrete has had time to set.

"When work is resumed, concrete previously placed should be roughened, thoroughly cleansed of foreign material and laitance, drenched and slushed with a mortar consisting of one part Portland cement and not more than two parts fine aggregate.

"The faces of concrete exposed to premature drying should be kept wet for a period of at least seven days.

"(b) Freezing Weather. The concrete for reinforced structures should not be mixed or deposited at a freezing temperature, unless special precau-

*From Joint Committee's recommendations, see footnote, page 15.

tions are taken to avoid the use of materials containing frost or covered with ice crystals, and in providing means to prevent the concrete from freezing after being placed in position and until it has thoroughly hardened.

"(c) Rubble Concrete. Where the concrete is to be deposited in massive work its value may be improved and its cost materially reduced through the use of clean stones thoroughly embedded in the concrete as near together as is possible and still entirely surrounded by the concrete."

JOINTS.

In walls of any considerable length it is necessary to provide against shrinkage and temperature cracks. The general practice for walls of plain concrete is to place contraction joints at intervals of from 30 to 50 feet, but in many instances this has not been sufficient and the author recommends a spacing of from 20 to 30 feet. Walls can be built with no joints by providing sufficient reinforcement to so distribute the temperature stresses that the cracks will be very minute and scarcely noticeable on close inspection.

SURFACES.

The proper treatment to give a pleasing appearance to exposed surfaces is one of the most difficult problems in concrete construction and a number of different methods have been employed, all of which are illustrated by different structures described in the text.

FORMS.*

"Forms should be substantial and unyielding, so that the concrete shall conform to the designed dimensions and contours, and should be tight to prevent the leakage of mortar.

"The time for the removal of forms is one of the most important steps in the erection of a structure of concrete or reinforced concrete. Care should be taken to inspect the concrete and ascertain its hardness before removing the forms.

"So many conditions affect the hardening of concrete that the proper time for the removal of the forms should be decided by some competent and responsible person, especially where the atmospheric conditions are unfavorable."

WATERPROOFING.

While many expedients have been used to render concrete impervious to water, experience has shown that, where the concrete is proportioned to realize

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*See footnote, page 15.

the greatest practicable density and is mixed to a rather wet consistency, it is sufficiently impervious itself, for ordinary purposes, without further treatment. The proportions generally used to resist the percolation of water range from 1:1:2 to 1:2:4, the latter being the most common mixture. Sometimes, where the mass of the concrete is considerable, or where the walls are thin, a material like hydrated lime or dry powdered clay may be efficient for void filling and permit the use of leaner proportions. In subways, long retaining walls, and reservoirs, cracks can be prevented by horizontal reinforcement properly proportioned and located. In any case, for water-tight work the concrete should be mixed wet enough to entirely surround the reinforcing metal and flow against the forms.

Asphaltic or coal tar preparations applied either as a mastic or with paper or felt are used to good advantage where it is deemed unadvisable to rely upon the natural imperviousness of the concrete itself.

DESIGN OF PLAIN CONCRETE.

In the design of plain concrete, sections should be so proportioned as to avoid tensile stresses, and while this may be accomplished in the case of rectangular shapes by keeping the line of pressure within the middle third of the section, in very large structures a more exact analysis may be required.

Inasmuch as structures of massive concrete are able to resist any unbalanced later forces by reason of their weight, a relatively cheap and weak concrete is often suitable for such conditions.

BENDING MOMENTS.

In reinforced concrete design as much variation may be had in the results by the selection of the bending moments as in the choosing of working stresses. If the members are continuous beams or slabs, special care must be taken in the design at the supports, since there is much and frequently more stress there than at the middle of the span. It is not safe practice to design a continuous beam in the center as though it was simply supported and then pay no attention to the design over the supports.

Good practice and the recommendations also of the Joint Committee on Concrete and Reinforced Concrete (1909) sanction the following formulas for bending moments:

Let P = concentrated load in pounds
w = unit distributed load in pounds per square foot (including the dead load)
l = length of member between centers of support in feet
M = bending moment in foot pounds.

To transform the bending moment to inch pounds, multiply by 12.

For beams and slabs simply supported at the ends and not continuous:

$$M = 1/8\ wl^2 \text{ for distributed load} \qquad (1)$$

and

$$M = 1/8\ wl^2 + 1/4\ Pl \text{ for distributed load plus a load concentrated at the center} \qquad (2)$$

For beams and slabs truly continuous and thoroughly reinforced over the supports:

$$M = 1/12\ wl^2 \text{ at the center of the member} \qquad (3)$$

$$\text{and } -M = 1/12\ wl^2 \text{ at the ends of the member} \qquad (4)$$

For beams and slabs partially continuous, as end spans, or for continuous members of 2 or 3 spans:

$$M = 1/10\ wl^2 \text{ at the center of the member} \qquad (5)$$

The negative bending moments which exist at the supports must be provided for by steel rods carried over the top of the support for tension and by a sufficient amount of concrete at the bottom of the beam near the support to take the compression.

If a part of the tension rods are bent up on an incline from about one-quarter points in the beam so as to pass horizontally through the top of the beam at the supports they must extend over the supports for a sufficient distance to transmit the compressive stress there, or must be firmly connected with corresponding rods in the adjacent bay. The total steel in the top must be sufficient to resist the tension due to negative moment, and the concrete and steel in the bottom next to the support, sufficient to resist the compression.

For cantilever beams, that is, beams with one end fixed and the other end free, where the maximum bending moment is at the point of support and the tension is in the top of the beam, the following formulas hold:

With a uniformly distributed load over the length of the beam:

$$-M = 1/2\ wl^2 \text{ at the support}$$

If also a live load is concentrated at the end

$$-M = Pl + 1/2\ wl^2$$

DESIGN OF REINFORCED CONCRETE.

In designing a reinforced concrete member it is not sufficient to simply determine the amount of steel required to resist the tensile stresses, but a most careful analysis must be made of all parts of the structure.

The correct design of reinforced concrete beams and girders involves the following studies:

(1) The bending moments due to the live and dead loads.

(2) Dimensions of beams which will prevent an excessive compression of the concrete in the top and which will give the depth and width which is otherwise most economical.

(3) Number and size of rods to sustain tension in the bottom of the beam.

(4) Shear or diagonal tension in the concrete.

(5) Value of bent-up rods to resist shear or diagonal tension.

(6) Stirrups to supplement the bent-up rods in assisting to resist the shear or diagonal tension.

(7) Steel over the supports to take the tension due to negative bending moment.

(8) Concrete in compression at the bottom of the beam near the supports due to negative bending moment.

(9) Length of rods to prevent slipping.

(10) End connections at wall.

WORKING STRESSES.

The working stresses for static loads given below follow the recommendations of the Progress Report of the Joint Committee on Concrete and Reinforced Concrete, 1909.*

> "General Assumptions. The following working stresses are recommended for static loads. Proper allowances for vibration and impact are to be added to live loads where necessary to produce an equivalent static load before applying the unit stresses in proportioning parts.
>
> "In selecting the permissible working stress to be allowed on concrete, we should be guided by the working stresses usually allowed for other materials of construction, so that all structures of the same class, but composed of different materials, may have approximately the same degree of safety.
>
> "The stresses for concrete are proposed for concrete composed of one part Portland cement and six parts aggregate, capable of developing an average compressive strength of 2,000 pounds per square inch at twenty-eight days, when tested in cylinders 8 inches in diameter and 16 inches long, under laboratory conditions of manufacture and storage, using the same consistency as is used in the field. In considering the factors rec-

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*The form of the tabulation is as given in the Report of the Committee on Reinforced Concrete of the National Association of Cement Users, 1909, Sanford E. Thompson, Chairman.

ommended with relation to this strength, it is to be borne in mind that the strength at twenty-eight days is by no means the ultimate which will be developed at a longer period, and therefore they do not correspond with the real factor of safety. On concretes in which the material of the aggregate is inferior, all stresses should be proportionally reduced, and similar reduction should be made when leaner mixes are to be employed. On the other hand, if, with the best quality of aggregates, the richness is increased, an increase may be made in all working stresses proportional to the increase in compressive strength at 28 days, but this increase shall not exceed 25 per cent.

"Diagonal Tension. In beams where diagonal tension is taken by concrete, the vertical shearing stresses should not exceed

2 per cent of compressive strength at twenty-eight days, or 40 pounds per square inch for 2,000 pound concrete.

"Bond for Plain Bars. Bonding stress between concrete and plain reinforcing bars,

4 per cent of compressive strength at twenty-eight days, or 80 pounds per square inch for 2,000 pound concrete.

For drawn wire,

2 per cent, or 40 pounds on 2,000 pound concrete.

"Bond for Deformed Bars.* Bonding stress between concrete and deformed bars may be assumed to vary with the character of the bar from

5 per cent to 7½ per cent of the compressive strength of the concrete at twenty-eight days or from

100 to 154 pounds per square inch for 2,000 pound concrete.

"Reinforcement. The tensile stress in steel should not exceed 16,000 pounds per square inch. The compressive stress in reinforcing steel should not exceed 16,000 pounds per square inch, or fifteen times the working compressive stress in the concrete.

"Modulus of Elasticity. It is recommended that in all computations the modulus be assumed as 1/15 that of steel; that is, that a ratio of fifteen be employed.

"Bearing.† For compression on surface of concrete larger than loaded area,

32.5 per cent of compressive strength at twenty-eight days or 650 pounds per square inch on 2,000 pound concrete.

"Plain Columns. Plain columns or piers whose length does not exceed twelve diameters,

*No recommendation for deformed bars is given in the report of the Joint Committee.

†For beams and girders built into pockets in concrete walls the lower compressive stress of 450 pounds per square inch should not be exceeded.

$22\frac{1}{2}$ per cent of compressive strength at twenty-eight days, or 450 pounds per square inch on 2,000 pound concrete.

"Reinforced Columns. (a) Columns with longitudinal reinforcement only, the unit stress recommended for plain columns.

(b) Columns with reinforcement of bands or hoops, as specified below, stresses 20 per cent higher than given for (a).

(c) Columns reinforced with not less than 1 per cent and not more than 4 per cent of longitudinal bars and with bands or hoops, stresses 45 per cent higher than given for (a).

(d) Columns reinforced with structural steel column units which thoroughly encase the concrete core, stresses 45 per cent higher than given for (a)."

"In all cases, in addition to the stress borne by the concrete given above, longitudinal reinforcement is assumed to carry its proportion of stress in accordance with the ratio of its elasticity to concrete. For example, with a working stress in concrete of 450 pounds per square inch, the longitudinal reinforcement may be assumed to carry $15 \times 450 = 6{,}750$ pounds per square inch.

"The hoops or bands are not to be counted upon directly as adding to the strength of the column.

"Bars composing longitudinal reinforcement shall be straight and shall have sufficient lateral support to be securely held in place until the concrete is set.

"Where bands or hoops are used, the total amount of such reinforcement shall be not less than 1 per cent of the volume of the column enclosed. The clear spacing of such bands or hoops shall be not greater than one-fourth the diameter of the enclosed column. Adequate means must be provided to hold bands or hoops in place so as to form a column, the core of which shall be straight and well centered.

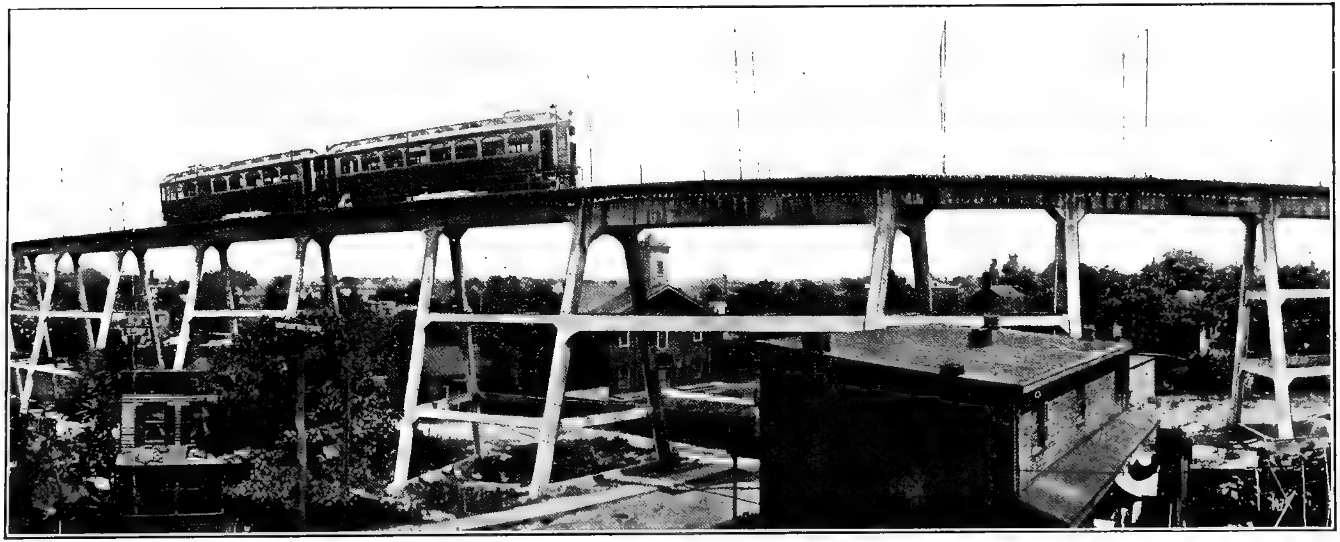
"Bending stresses due to eccentric loads must be provided for by increasing the section until the maximum stress does not exceed the values above specified.

"Compression in Extreme Fiber. For extreme fiber stress of beams calculated for constant modulus of elasticity.

32.5 per cent of the compressive strength at twenty-eight days, or 650 pounds per square inch for 2,000 pound concrete.

"Adjacent to the support of continuous beams, stresses 15 per cent greater may be allowed.

"Shear. Pure shearing stresses uncombined with compression or tension. 6 per cent of compressive strength at twenty-eight days, or 120 pounds per square inch for 2,000 pound concrete."



RICHMOND VIADUCT, RICHMOND AND CHESAPEAKE BAY RY.

CHAPTER III.

BRIDGES.

One of the most important applications of concrete to railroad construction is in the building of bridges. By the intelligent use of reinforced concrete, bridges are being designed which are superior to similar steel, masonry or wooden structures from an artistic, structural and economic standpoint.

While the life of a wooden bridge is about 9 years and of a steel bridge probably not over 30 to 40 years, and even then with a continual outlay for repairs and painting in addition to careful inspection, a concrete bridge will last almost indefinitely and with practically no maintenance. In addition to its natural permanence, such a bridge is proof against tornadoes, high water and fire.

Steel and wooden bridges grow weaker from rust and decay and in a few years the day comes when the bridge of decreasing strength is overloaded by the increasing weight of rolling stock and requires either strengthening or replacing. Concrete bridges on the other hand grow stronger with age and in probably as rapidly an increasing ratio as the increase of traffic.

A concrete bridge is free from the excessive vibrations often experienced in steel bridges and from disagreeable noise.

Track is easily maintained on such a structure, since the ordinary track ties and ballast take the place of the more expensive bridge ties of a steel structure.

In the construction of a concrete bridge there is no obstruction of traffic from swinging booms as is the case when setting stone of large dimensions in masonry bridges, nor so much difficulty in securing the necessary skilled labor during times when the building trades are active. The materials used can generally be obtained in the immediate vicinity of the bridge site.

The cost of a reinforced concrete bridge in almost all cases will be considerably less than that of a stone masonry structure and will not greatly, if at all, exceed that of a steel bridge, when the cost of piers and abutments is included in the comparison. Even when the cost of the steel is less, the difference is more than counteracted by the practically negligible maintenance costs of the concrete structure.

ARCH BRIDGES.*

While arch bridges may be constructed of either plain or reinforced concrete, the latter type is usually the most satisfactory, as the steel reinforcement not only permits the use of less material, but it also adds to the safety against settlements of foundations or centerings, and temperature stresses. The Wallkill River bridge shown in Fig. 3 is an interesting example of plain concrete construction, while the Jackson Street arch, the Paulins Kill viaduct and the Vermillion River Bridge, shown in Figs. 4, 8 and 9, are types of reinforced arch bridges.

Arches are classified in various ways, but the most simple classification is in reference to the method of the construction of the spandrels, or spaces above the upper surface of the arch ring and below the road-bed level. These spaces are either filled in solid with loose filling or are left open by skeleton spandrel construction consisting of slabs and beams supported on columns or cross-walls resting on the arch ring.

SOLID FILLED SPANDRELS. This type of construction is generally employed for arches of spans under 100 feet. While the solid-filled spandrels usually consist of an embankment of earth, sand or cinders enclosed between solid spandrel walls having the common trapezoidal retaining-wall section, or between reinforced spandrel walls, sometimes a filling of very lean concrete is used in place of the loose material, when the spandrel walls become an integral part of the filling. The loose filling between spandrel walls is deposited in thin layers and thoroughly tamped by ramming, rolling or flooding it in with water.

The Jackson Street arch, described on page 30, is an example of the solid fill spandrel type of construction.

SKELETON SPANDREL CONSTRUCTION. For spans of about 100 feet or over the skeleton spandrel construction is, on account of its reduced weight and cost, found most advantageous.

In addition to the advantage resulting from a reduction of the load on the main arch ring and foundations this type of construction when well handled furnishes an opportunity to introduce architectural effects of great beauty. By doing away with the long and heavy solid spandrel walls the trouble with temperature strains is greatly lessened in this type of construction.

The Paulins Kill Viaduct and the Vermillion River Bridge, described on pages 34 and 36, are examples of skeleton spandrel construction.

Another form of skeleton spandrel construction, an example of which is found in the Connecticut Avenue Bridge, Washington, D. C., consists of hol-

*For theory and methods of design see Taylor & Thompson's "Concrete Plain and Reinforced," Second Edition, 1909, or Howe's "Symmetrical Masonry Arches." John Wiley & Sons, New York, publishers.

FIG. 3.—WALLKILL RIVER VIADUCT, ERIE AND JERSEY R. R.

low spandrels with curtain walls forming a cellular spandrel construction in which the roadway is carried on a system of braced columns and beams enclosed by thin curtain walls on each side of the bridge.

EXPANSION JOINTS. To provide for the action of temperature strains, expansion joints are generally constructed in the spandrels where they meet the abutments and usually also at one or more points between the abutments and crown of the arch. Some engineers place a vertical expansion joint over each springing line and at a point about 10 feet each side of the crown. These joints which cut the spandrels vertically from the coping of the parapet wall to the arch ring are either constructed as mere planes of weakness in the concrete or as actual joints filled with one or more layers of felt, corrugated paper or some other partially elastic material.

Another method which is sometimes adopted is to entirely omit the expansion joints and resist the temperature strains by providing sufficient reinforcing metal throughout the structure.

WATERPROOFING. The top of the arch and the lower parts of the spandrel walls are usually waterproofed in order to facilitate drainage and keep accumulated water from penetrating the arch ring.

In addition to the structures described below, a number of other arch bridges are shown among the miscellaneous photographs in the back of the book.

JACKSON STREET ARCH, C. R. R. OF N. J. As will be seen by the drawings in Fig. 5, page 32, which show the essential features of design and construction, this bridge consists of a reinforced concrete arch of 54 ft. 3 inch clear span with axis on a skew of 22° 2′ with the axis of the street. The photograph in Fig. 4 shows the finished arch.

The abutments and wing walls rest on 10-inch piles, the last three rows in each abutment being driven with a batter to correspond with the inclination of the line of pressure. These piles were cut off below water level, which is about 10.87 feet below the surface of the street, and a bed of broken stone 3 feet thick was rammed around them to within 6 inches of the tops where the concrete work started.

With the exception of an open expansion joint, like a vertical tongue and groove, between the ends of the abutments and the ends of the wing walls the bridge was constructed as a monolith. For the arch ring the concrete was mixed in the proportions of 1 part Atlas Portland Cement, 2 parts sand and 4 parts 1-inch screened broken stone, while for the abutments and wing walls the proportion was 1:3:6 with 1½-inch stone and for the spandrel walls 1:3:5, with 1-inch stone.

The main reinforcing for the arch consists of 1¼-inch curved round rods in both intrados and extrados placed about four inches from the upper and

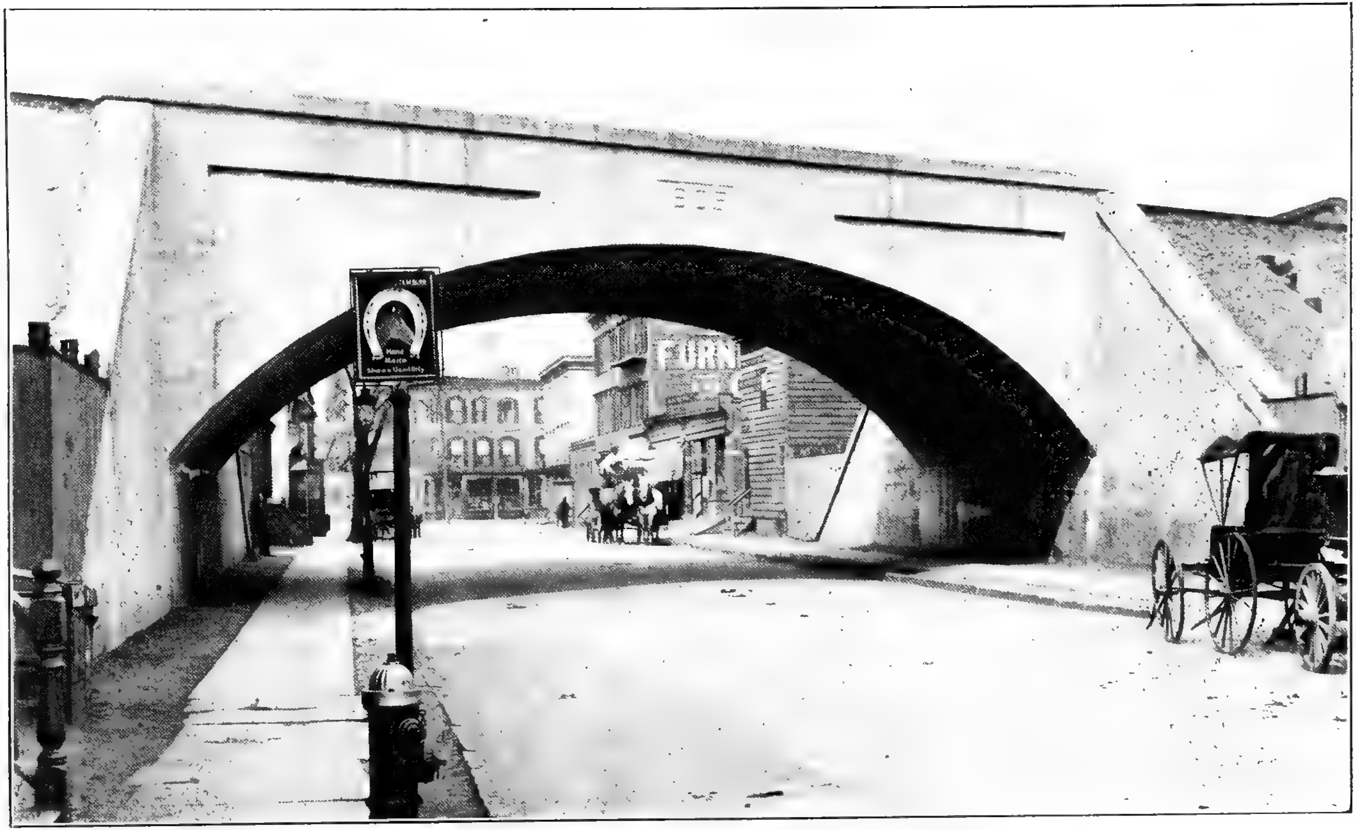


FIG. 4. JACKSON STREET ARCH, NEWARK, N. J., C. R. R. OF N. J.

lower surfaces. In the intrados they are spaced 12 inches apart at the springing line and extend 5 feet past the center, thus giving a spacing of 6 inches for 32 feet at the crown. In the extrados they are 12 inches apart at the abutments and carry 2½ feet beyond the center line, thus giving a 5 foot lap for bond. At the haunches auxiliary rods about 26 feet long are placed in all the spaces between the main rods. Above and below both the intrados and ex-

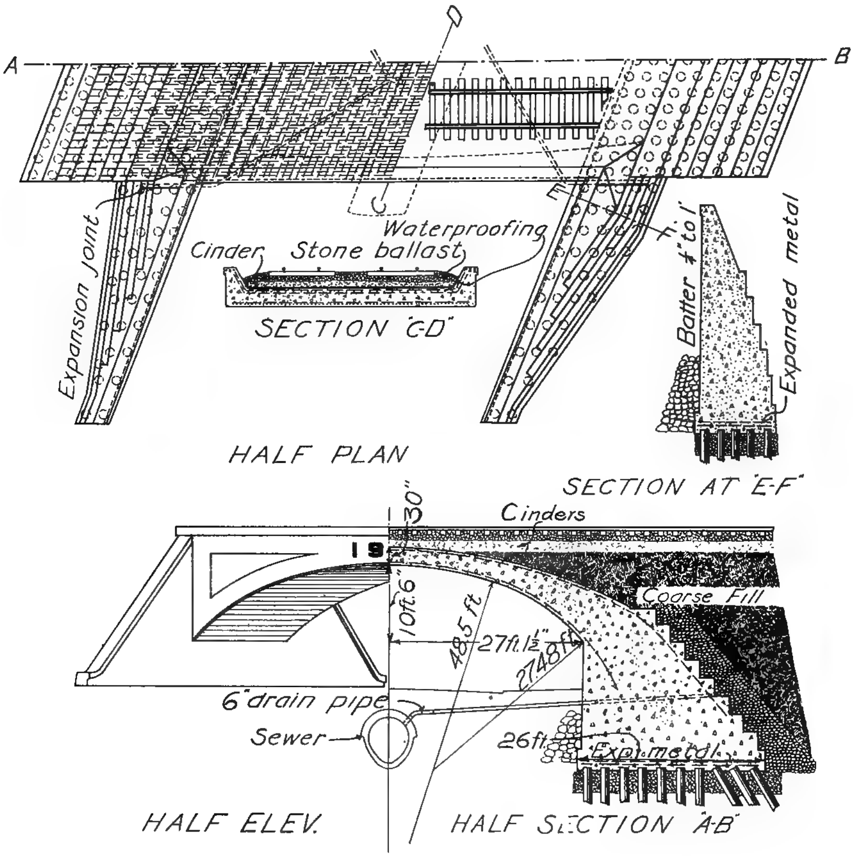


FIG. 5.—JACKSON STREET ARCH, C. R. R. OF N. J.

trados rods, horizontal transverse ¾-inch rods are spaced 24 inches apart and extend the full length of the arch.

In designing the bridge the stress in the arch ring was computed by the graphical method of Prof. W. A. Cain, the live load assumed being the standard loading of the Central Railroad of New Jersey or 700 pounds per square foot of surface while the dead load was figured as follows: Rails, ties, ballast,

140 pounds per square foot of surface; filling, 100 pounds per cubic foot, and concrete, 160 pounds per cubic foot. Including temperature stresses the maximum stress in the concrete was 600 pounds per square inch compression and 50 pounds per square inch shear, while the maximum stress in the steel was 18,000 pounds per square inch in tension and 5,000 pounds per square inch in compression, the latter value being fixed of course by the permissible stress in the concrete times the ratio of elasticity of steel to concrete.

During the construction of the bridge, railroad traffic was maintained uninterruptedly on temporary trestles on either side of the bridge.

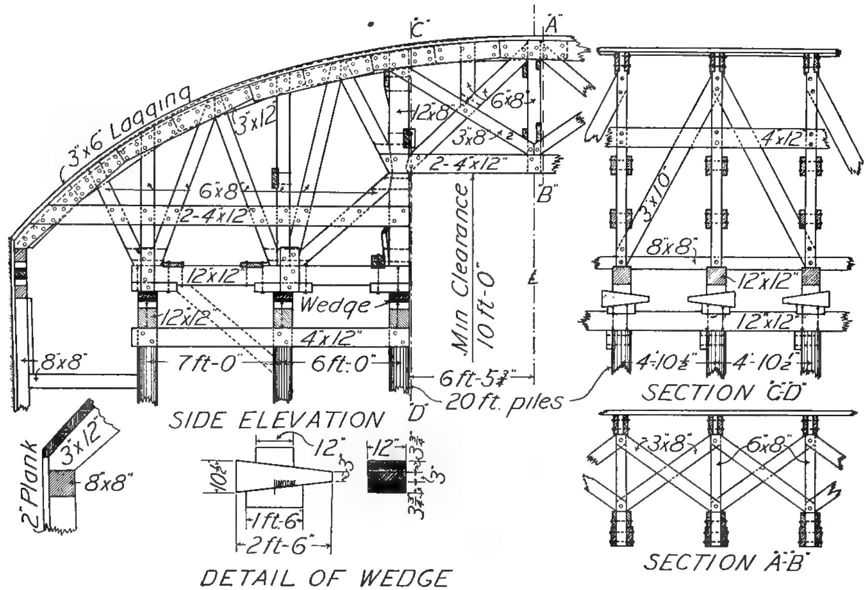


FIG. 6.—FORMS FOR JACKSON STREET ARCH.

The arch forms were assembled on the ground, and after the abutments were well under way they were swung into place from an erection car on the temporary trestle. The photograph in Fig. 7 shows the method of placing these centers. The concrete in the abutments and the filling behind them was carried to a point about 2 feet above the spring line of the arch, when the arch ring was put in at one operation, concreting commencing simultaneously at the springing lines of both abutments.

The concrete was mixed in a 1 cubic yard Ransome Mixer on one side and a 1 cubic yard Smith Mixer on the other, and was deposited from ordinary iron wheelbarrows.

With the exception of the tops of the spandrel and wing walls, which were finished with a 1-inch trowelled surface of cement mortar applied simultaneously with the last course of concrete, the finish of the concrete was obtained by simply spading back the concrete from the forms.

The upper surface of the arch is waterproofed with four coats of Hydrex felt mopped on with Hydrex compound applied hot, and the backfill is drained from the ends of the abutments by two 6-inch cast-iron pipes connecting with the city sewer in the center of the street as shown.

The bridge was designed by the engineering department of the railroad.

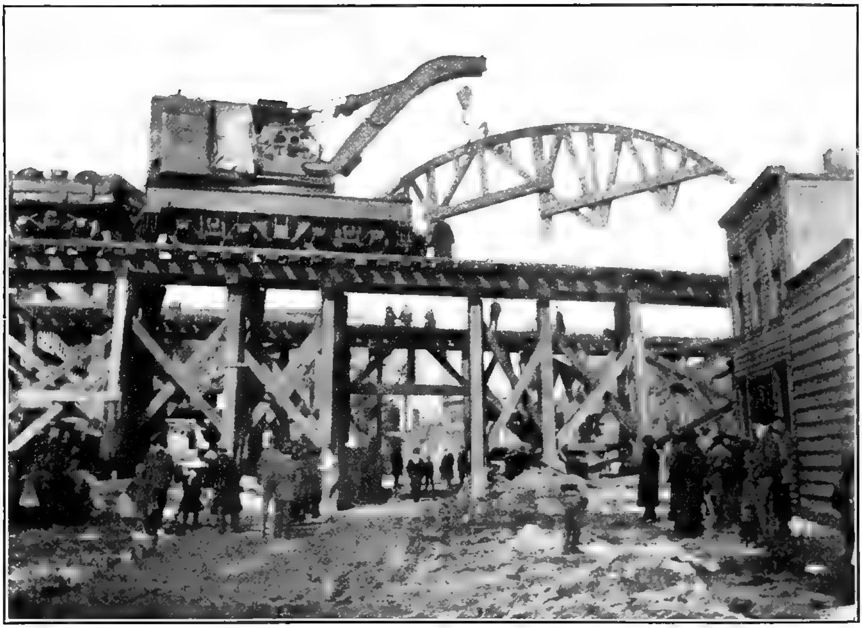


FIG. 7.—SETTING ARCH CENTERS.

Mr. J. O. Osgood, Chief Engineer, and was constructed under their supervision in the spring of 1904 by Holmes and Coogan of Jersey City.

PAULINS KILL VIADUCT, D., L. & W. R. R. This bridge, under construction in 1909, is approximately 1100 feet long and 115 feet high and consists of five 120-ft and two 100-ft. reinforced arches with skeleton spandrel arches supporting the track.

The drawings in Fig. 8 show the details of construction of a typical arch span and pier, together with one of the reinforced abutments. The design of these abutments furnished a rather novel and economical feature inasmuch as

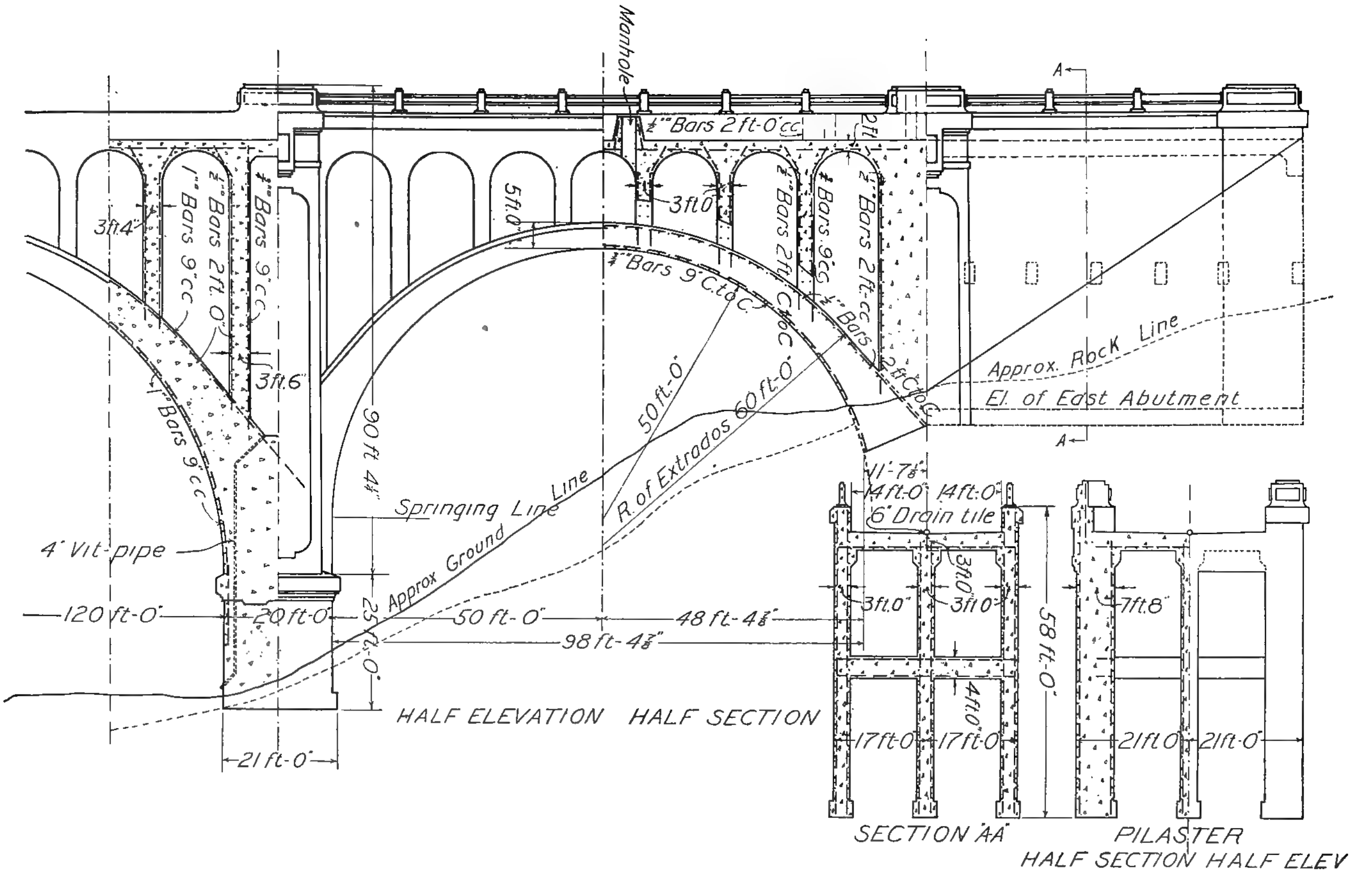


FIG. 8.—TYPICAL ARCH SPAN, PAULINS KILL VIADUCT, D., L. & W. R. R.

they are composed of three longitudinal reinforced walls carrying a reinforced slab which supports the track and ballast. This skeleton construction allows the embankment to take its natural slope between the walls as well as on the outside of them, and by thus balancing the earth pressure does away with the bulky section which would have been necessary had they been designed as retaining walls.

With the exception of the copings and ornamental railings, which are of 1:2:4 proportions, the concrete throughout the structure is mixed in the proportions of 1 part cement, 3 parts sand and 5 parts broken stone. In the abutments and piers for the arches and foundations below the ground line, large quarry stones are bedded in the concrete so as to form a rubble concrete and reduce the most of materials.

In designing the viaduct a ratio of elasticity of steel to concrete of 15 was assumed and the concrete was figured at 600 pounds per square inch safe working fiber stress, 500 pounds per square inch direct compression and 50 pounds per square inch shear, while the steel was given a working tensile stress of 16,000 pounds per square inch.

The structure was designed by the engineering department of the Delaware, Lackawanna and Western Railroad under the supervision of Mr. Lincoln Bush, Chief Engineer, with Mr. B. H. Davis, Assistant Engineer in charge of masonry design, and Mr. F. L. Wheaton, Engineer of Construction in charge of work in the field.

VERMILLION RIVER BRIDGE, C., C., C. & ST. L. RY. In its essential features this bridge is similar in type and design to the Paulins Kill Viaduct illustrated in Fig. 8 and consists of three arches, the central span being 100 feet and the two side spans 80 feet, with rises of 40 and 30 feet respectively.

The photograph in Fig. 9 is of the completed structure, while Fig. 10 is a view taken during the construction showing the false work for the main arches and the location of the derricks.

The arch rings are 3½ feet thick at the crown, deepening out toward the spring lines, and are reinforced near the extrados and intrados with 1-inch corrugated bars 12 inches apart and overlapped 4 feet at their ends, thus giving a bond of 40 diameters. Below these rods at the extrados and above them at the intrados there is a series of ⅞-inch transverse bars 33 feet long.

Above the arch rings of the main arches the channel piers are hollow, the pilasters being carried up as reinforced facing slabs 15 feet wide and 3½ feet thick. The transverse walls are formed by the piers of the spandrel arches next to the springings, which have brackets at the top projecting 12 inches on the inside. These brackets carry reinforced concrete slabs 2 feet thick, which,

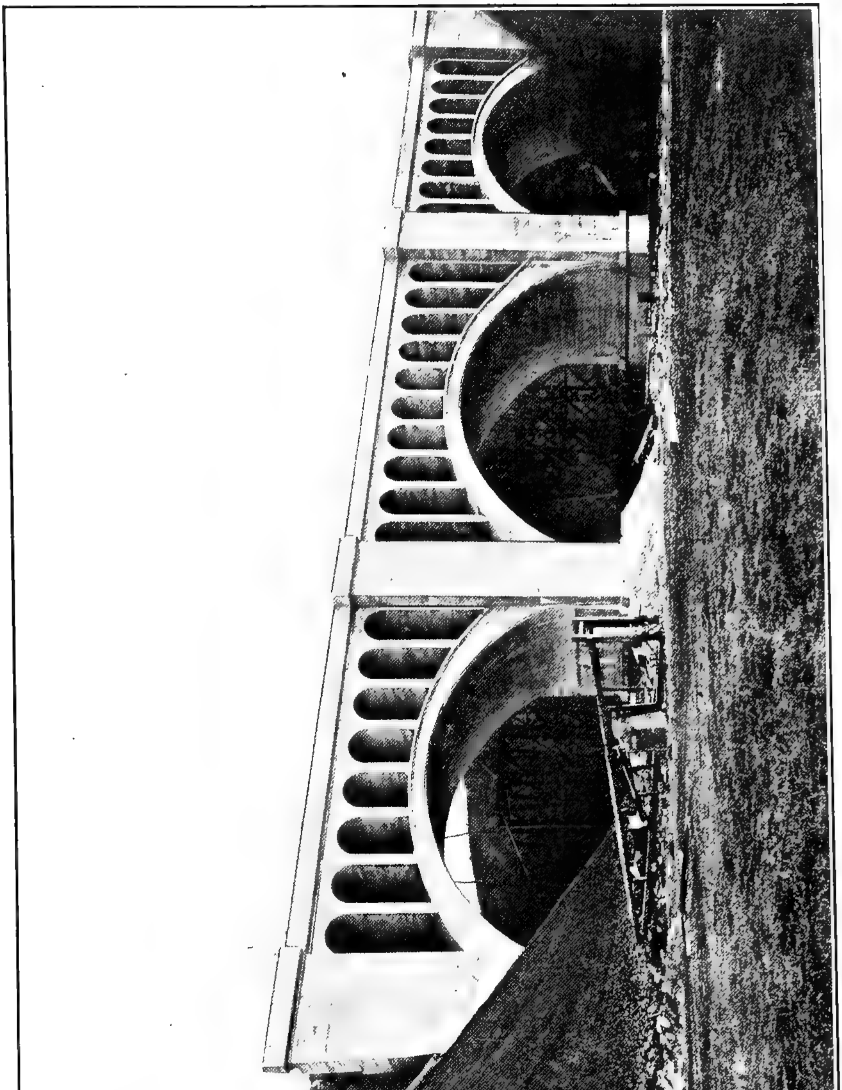


FIG. 9.—VERMILLION RIVER BRIDGE, BIG FOUR RY.

being freely supported on rails embedded in the tops of the piers and bearing against similar rails projecting from the underside of the slabs, act as expansion joints. A similar transverse expansion joint is placed over the top of each abutment.

The concrete in these joints was made as smooth and flat as possible and finished so that contact between the adjacent faces at the point is made only through the embedded rails. To further separate the division two layers of felt are placed between the two surfaces of concrete and carried up to within

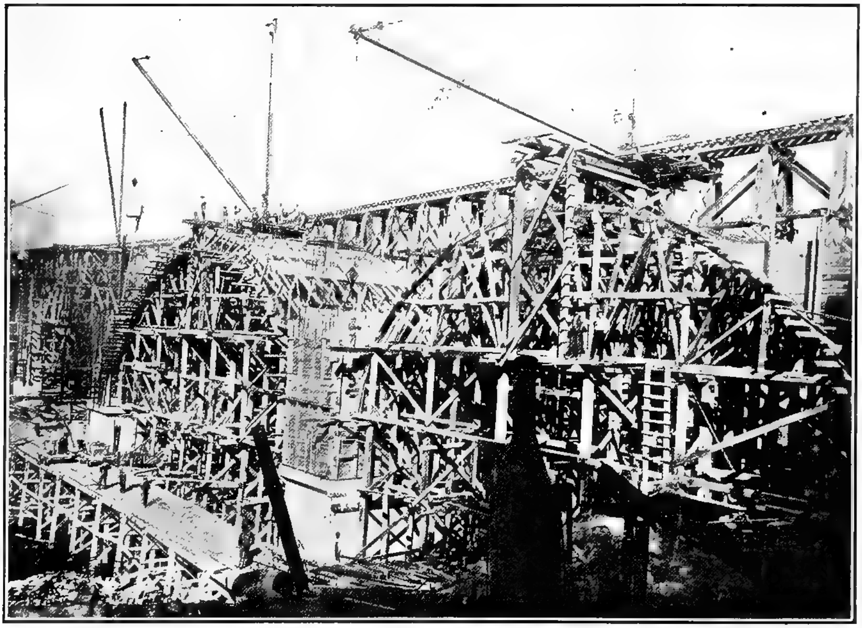


FIG. 10.—FALSE WORK FOR MAIN ARCHES.

2 inches of the top of the vertical joints, the remaining space being filled with asphalt.

The concrete for the reinforced portions was mixed in the proportions of 1 part cement to 2 parts clean sand to 4 parts of broken stone; that for the abutments and main piers of 1:3:6 and the footings of 1:4:8 proportions.

The bridge was designed in the construction department of the Cleveland, Cincinnati, Chicago and St. Louis Ry. and was built by the Bates and Rogers Construction Company of Chicago in the fall of 1905.

WALLKILL RIVER VIADUCT, E. & J. R. R. This is a very heavy

unreinforced concrete bridge 388 feet long, having a width of 32 feet between outside of parapet walls, and consists of four 60-ft. and two 40-ft. circular arches. The photograph in Fig. 3, page 29, is of the finished structure, while the drawings in Fig. 11 show the plan, elevation and section of the 60-ft. arches, together with details of the expansion joints, which occur at each pier, extending from the top of coping to top of haunch. The starkweather is also drawn in detail.

The bridge, which contains 7500 cubic yards of concrete, was designed by

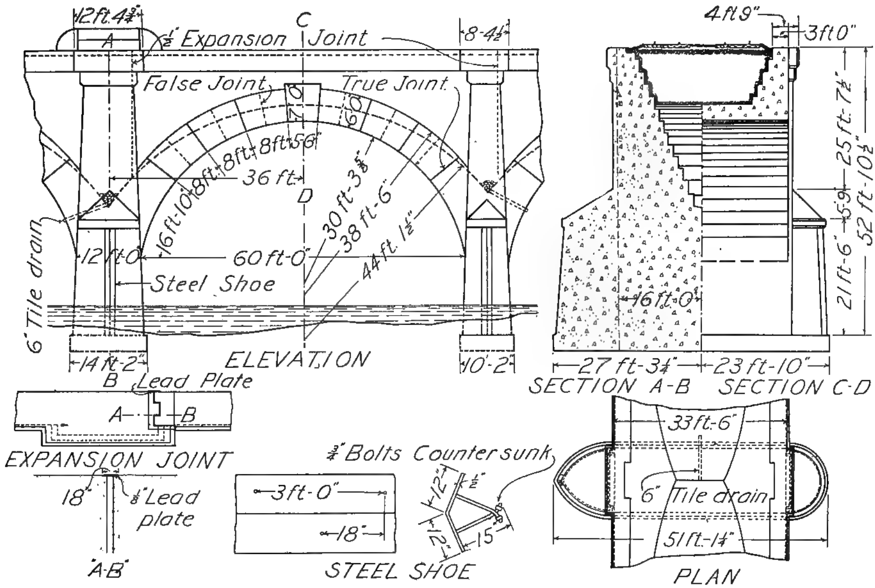


FIG. 11.—DETAILS OF 60-FT. ARCH, WALLKILL RIVER VIADUCT.

the engineering department of the Erie Railroad under the supervision of Mr. F. L. Stuart, Chief Engineer, and was built by Lathrop, Shea and Henwood Company of Scranton, Pa.

GIRDER BRIDGES.

When constructed of concrete, girder bridges are designed either as entire reinforced concrete structures or as a combination of structural steel and reinforced concrete. In the latter case the main girders and cross beams are generally composed of structural shapes encased in concrete with the floor slabs of reinforced concrete. An example of the former type, which contains a number

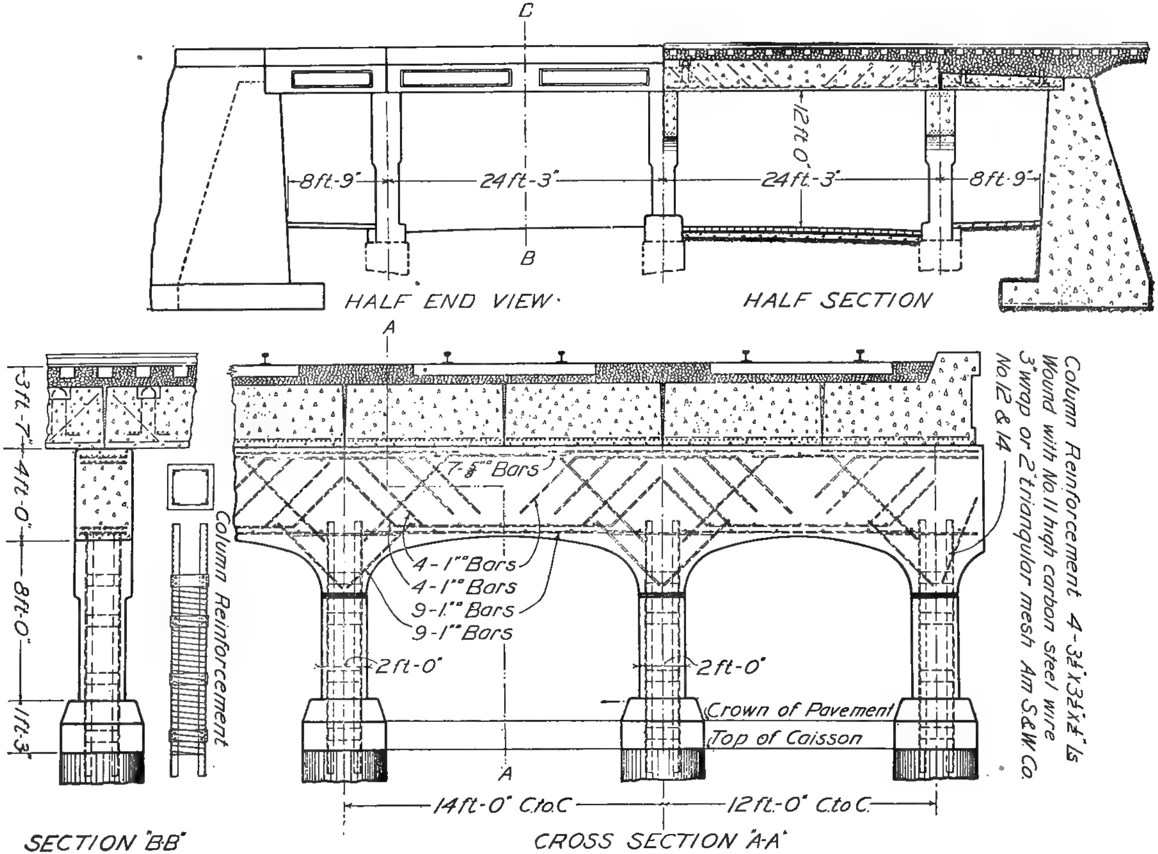


FIG. 12.—TYPICAL DETAILS, C., B & Q. R. R. TRACK ELEVATION.

of advanced and novel features, is described below, while the First Avenue Viaduct described on page 57 is an interesting example of the latter type.

Among the miscellaneous photographs in the back of the book are shown other girder bridges of both types.

In designing reinforced concrete girder bridges, care should be taken to see that there is sufficient concrete and steel provided for shearing stresses, as with short spans and heavy loads this will be found in many cases to be the determining factor.

TRACK ELEVATION WORK, CHICAGO, ILL., C., B. & Q. R. R. In connection with the track elevation work which the Chicago, Burlington & Quincy Railroad is carrying on between Canal Street and Blue Island avenue, Chicago, there are a number of reinforced concrete girder bridges forming subways similar in type and design to the drawings shown in Fig. 12. These

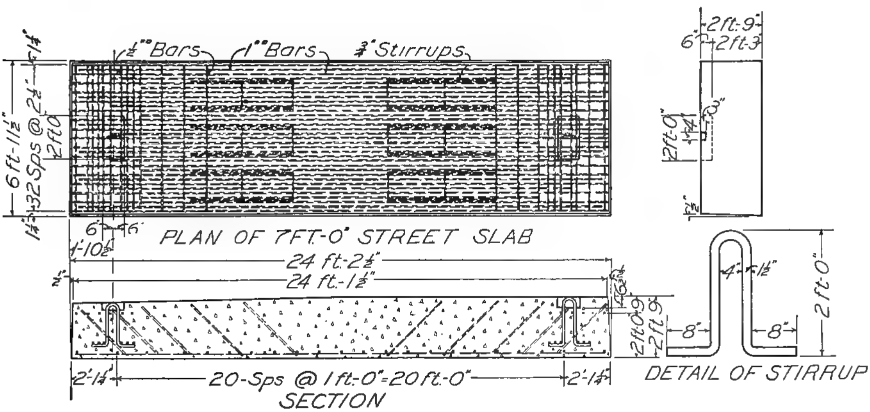


FIG. 13.—DETAILS OF TYPICAL SLAB, C., B. & Q. R. R. TRACK ELEVATION.

bridges are notable because of their extremely large size and capacity and for their methods of construction. As will be seen from the drawings in Fig. 12, the essential features of design and construction of a typical bridge consist of reinforced concrete columns and cross girders cast in place and carrying reinforced deck slabs which were moulded in sections away from the bridge site and when properly cured were transported on flat cars and set in place by a wrecking crane. After being thoroughly waterproofed the ballast and track was laid directly on these slabs. Fig. 13 shows the details of a typical slab.

The columns and cross girders are composed of concrete mixed in the proportions of one part cement to four parts pit-run gravel. The columns are reinforced with four 3½ by 3½ by ½ inch angles hooped spirally with high carbon steel wire. The girders and slabs are reinforced with corrugated bars.

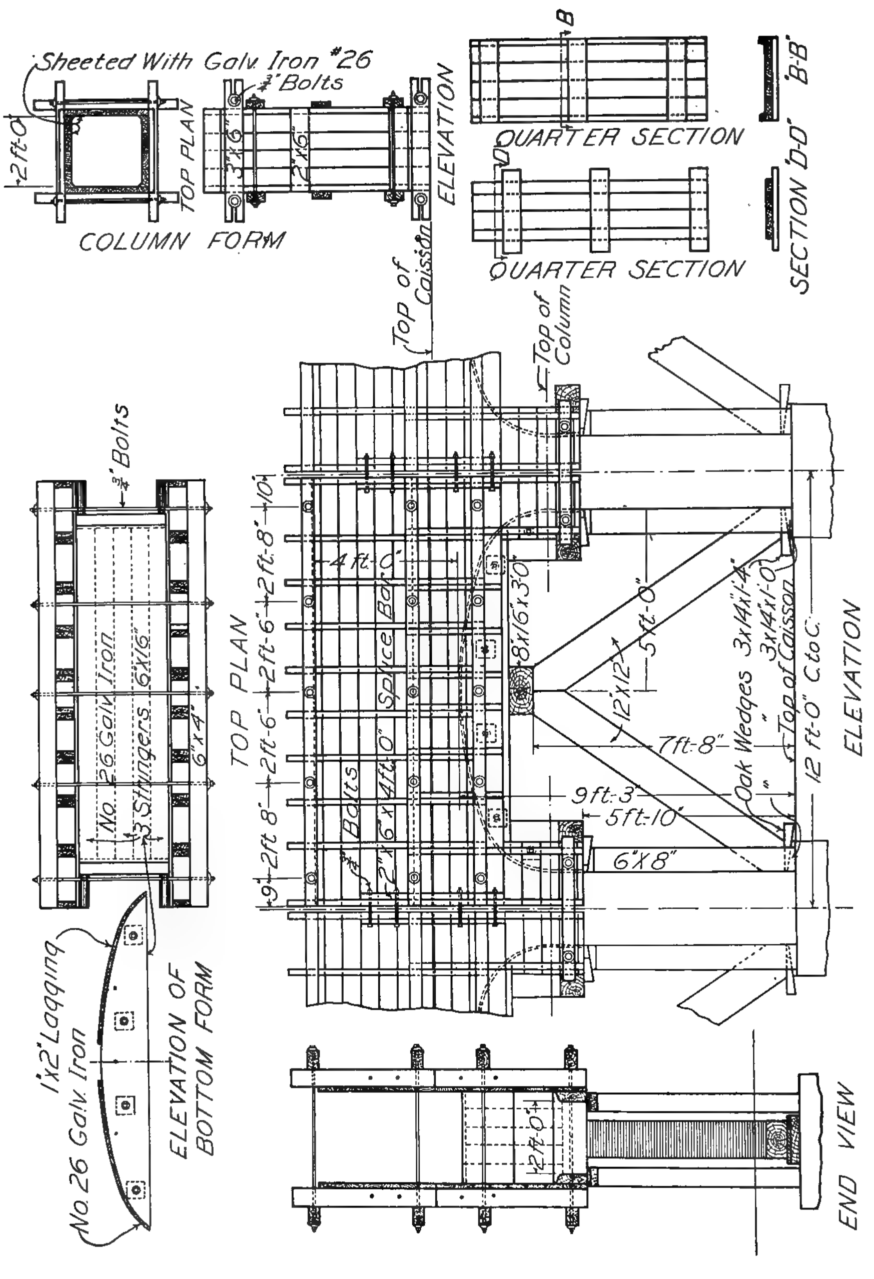


FIG. 14.—FORMS FOR COLUMNS AND GIRDERS, C., B. & Q. R. R. TRACK ELEVATION.

Fig. 14 shows the forms used in the construction of the girders and columns.

The slabs were built along both sides of a switch track in one of the railroad yards near the city limits and after curing ninety-days were picked up by a locomotive crane and placed on flat cars and hauled to a convenient storage place where they were piled three high until required at the bridge site.

Each slab was built in a separate form and after being cast was wet thoroughly every evening for two weeks. The slabs were made with the ends and sides battered so as to have a clearance of ¼ inch between them at the bottom and 1 inch at the top on both sides and both ends. These spaces were

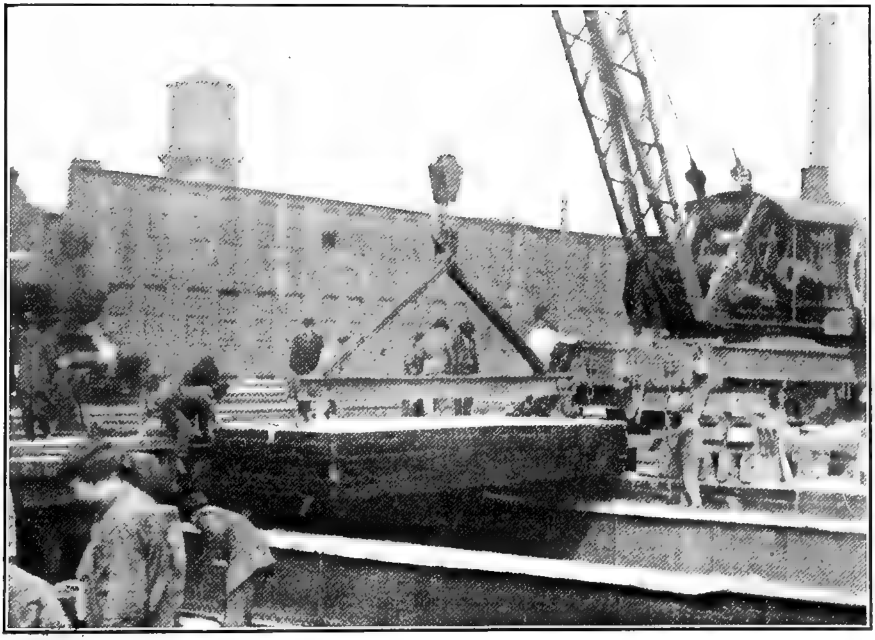


FIG. 15.—SETTING CONCRETE SLABS, C., B. & Q. R. R. TRACK ELEVATION.

filled with waterproofing, thus making the whole bridge floor water tight. A mixture of one part cement to four parts gravel was used in their construction. The slabs for the long spans contain approximately 19.2 cubic yards of concrete and weigh 36 tons each.

In handling and setting the slabs, a 100-ton locomotive crane equipped with a special toggle frame was used. The photograph in Fig. 15 shows this crane in the act of setting one of the long span slabs.

This work is designed and constructed by the Engineering Department of the railroad under the supervision of Mr. C. H. Cartlidge, Bridge Engineer.

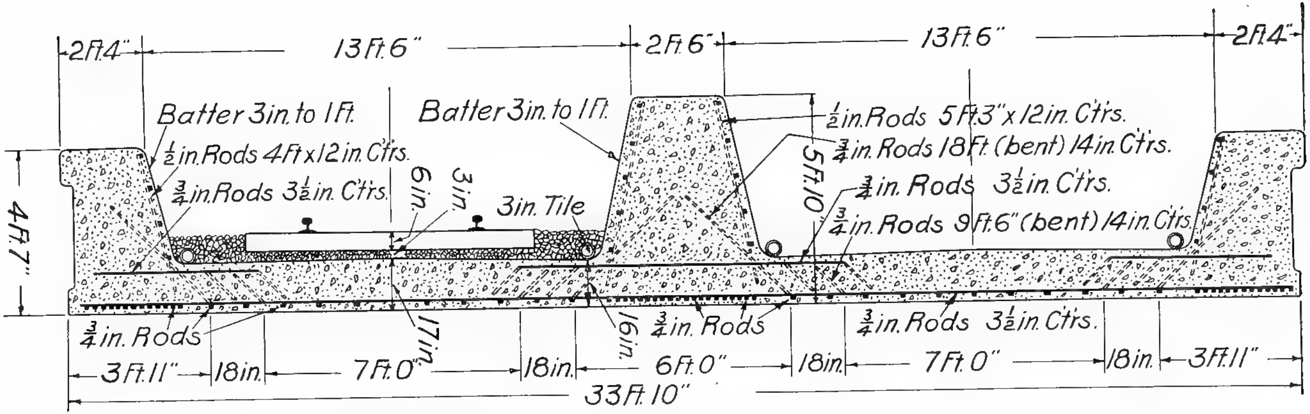


FIG. 16.- CROSS SECTION OF THROUGH GIRDER BRIDGE, C., B. & Q. R. R.

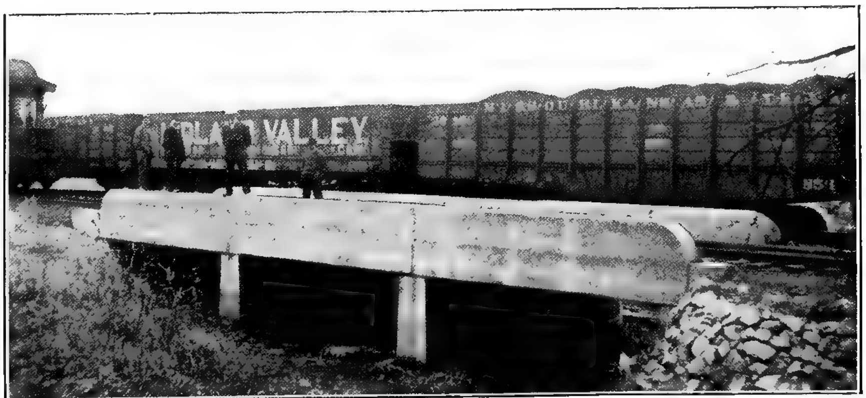


FIG. 17.—THROUGH GIRDER BRIDGE, C., B. & Q. R. R.

THROUGH GIRDER BRIDGE, C., B. & Q. R. R.—In Fig. 16 is shown the cross section of a reinforced concrete double track through girder bridge of 20 feet 3 inch skew span, which is of interest since this form of construction is employed to good advantage where the headroom is limited and a deck girder could not be placed. It will be seen that the two outer girders act as parapets and that the ballast is laid directly on the suspended floor slab. The photograph in Fig. 17 is of a similar type of construction of 18 foot skew span.

TRESTLES.

Reinforced concrete is being used for trestles of every class. In the majority of cases these are conservative and safe, but a few of the designs along the lines commonly employed in steel construction with very high bents are considered by many conservative engineers to be extreme.

In structures of this type the utmost caution should be employed in the mechanics of design to see that all parts are symmetrical, that the column design is conservative and that proper provision is made for temperature stresses.

While the cost of a reinforced trestle is greater than that of a timber structure, this difference is often more than offset by the temporary character and the danger from conflagration of the latter type. As compared to steel construction, reinforced concrete is generally cheaper and possesses the additional advantage of being free from constant inspection, painting and general maintenance.

A number of very long and high trestles have been constructed during the past few years of reinforced concrete, one of the largest being the Richmond and Chesapeake Bay Viaduct described below.

The Chicago, Burlington & Quincy Railroad are changing over all the wooden pile trestles on their line to similar reinforced concrete structures, a typical example of which is shown on page 22.

A number of other reinforced concrete trestles are shown among the miscellaneous photographs at the back of the book.

RICHMOND VIADUCT OF THE RICHMOND AND CHESAPEAKE BAY RAILWAY.—The Richmond and Chesapeake Bay Electric Railway enters Richmond over a reinforced concrete viaduct 2,800 feet long, ranging in height from 18 feet at either end to 70 feet at its highest point. A riveted steel girder viaduct was first contemplated, but was rejected on account of the high initial cost and cost of maintenance, as well as the difficulty of double tracking such a structure should it become necessary. A wooden trestle was then planned, and some of the timber ordered and partially delivered, when considerations of fire protection as well as the necessarily temporary character

of wood construction persuaded the company to adopt a reinforced concrete structure.

Bids for the design of such a structure were then called for, the railroad company submitting only the general location, profile and prescribed loads. Under these conditions the design of the New York branch of the Trussed Concrete Steel Company, Mr. B. J. Greenhood, Engineer, was accepted and the contract for the construction of the viaduct awarded to Mr. John T. Wilson, of Richmond, Va.

FIG. 18.—VIEW AT CURVE, RICHMOND VIADUCT.

The viaduct was designed to carry a 75 ton car, 54 ft. long on four-wheeled trucks placed 33 ft. apart, each truck consisting of two axles 7 ft. on centers. In computing the sizes of the various members it was assumed that the viaduct should carry its dead load and the entire live load plus 50 per cent of the live load for impact. The longitudinal thrust due to the braking of trains was assumed as 20 per cent of the live load. At the curves, overturning moments were allowed for at the rate of 2 per cent for each degree of curvature. Wind pressure was figured at 30 pounds per square foot on the surface of train and viaduct.

For the superstructure, it was decided to use concrete mixed in the pro-

portions of 1 part Atlas Portland Cement, 2 parts granite dust and 4 parts ¾-inch crushed granite, and in the footings a 1:2½:5 mixture of the same materials. The columns were designed for a compressive stress of 500 pounds per square inch on the concrete and 6,000 pounds per square inch on the longitudinal reinforcing steel. In designing the girders, continuous beam action was assumed and the concrete was figured at 600 pounds per square inch extreme fiber stress and 50 pounds per square inch shear, while the steel was given a tensile stress of 16,000 pounds per square inch. In proportioning the footings, which bear on either hard clay or compact gravel, a bearing

FIG. 19.—VIEW FROM GROUND, RICHMOND VIADUCT.

value of 3 tons per square foot was figured on for all possible stresses including future double tracking. Kahn trussed bars were used as reinforcing for the entire structure.

The viaduct is comprised of a system of girders of rectangular cross section varying in span from 23 to 68 feet supported by a series of interbraced and battered bents varying from 14 to 70 feet in height. The general features of design and construction of the different types of cross section of the viaduct are readily understood from the accompanying drawings shown in Fig. 20.

As will be noted by the photograph in Fig. 19, the diagonal bracing which

is generally seen on structural steel towers is replaced by transverse and longitudinal struts, the intention being to design all joints and all members so that they will have the rigidity to withstand bending. Provision has been made for double tracking the viaduct, when traffic warrants such an extension, by building the footings for all bents over 20 feet in height, with an offset column base to which new columns can be attached and by leaving cored holes in the girders for connecting the new work. Both of these features are shown clearly in Fig. 20.

Expansion joints have been provided where the short girders rest on the column brackets, at intervals of about 200 feet, consisting of a grooved steel plate on top of the bent, on which a planed steel plate on the bottom of the girder slides; together with steel toggle connections at the upper part of the girder which prevent any tendency to turn the girder. Fig. 21 shows the details of construction of one of the 49 ft. girders.

An idea of the massive proportions of the trestle can be obtained by a study of the photographs in Fig. 18 and Fig. 19.

The track consists of 80 pound rails spiked to 8 x 8 inch cross ties 12 inches on centers which are notched 1½ inch over and bolted to 6 x 12 inch sleepers embedded in and attached to the concrete girders by means of anchor bolts as shown in Fig. 20. On the curves, heavier sleepers are used under the outside rail as shown in Fig. 20 in order to gain the necessary outer elevation.

The guard rail is made of 8 x 10 inch hard pine notched 2 inches between the ties. By extending every fifth tie four feet beyond the concrete girder and covering this extended tie with planking, a footway 40 inches wide is provided. In a similar manner the poles for carrying the trolley wires are supported.

Work on the structure was started in the spring and finished in the fall of 1906.

In the construction of the viaduct, one mixing plant, transferable from one place to another, consisting of one No. 2½ rotary mixer, hoisting engine, elevator, buckets, etc., was used. After the erection of the forms the columns and struts up to the bottom of the girders were poured at one continuous operation. The column forms were built in three sides forming a U-shape, and the fourth side built up in sections as the concrete was poured. The girders and floors were also put in at one operation.

The forms were made of 2-inch lumber dressed on one side, supported by falsework consisting of a 4 by 4 inch and 6 by 6 inch timbers. The girder sides were removed at the end of a week while the remaining forms and supporting falsework were left in place for at least thirty days. After the removal of the forms the entire surface of the viaduct was given a finish of sand and cement applied with a brush.

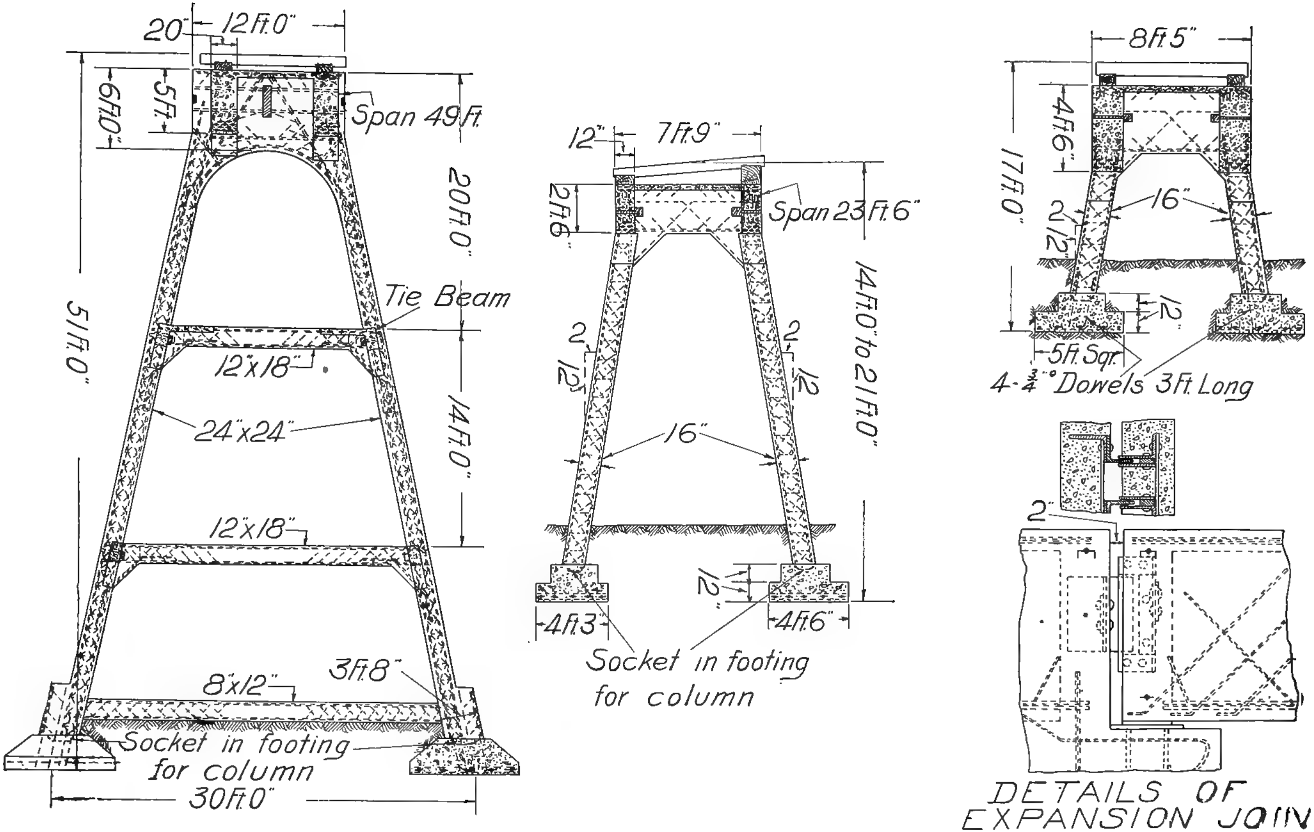


FIG. 20—TYPICAL BENTS, RICHMOND VIADUCT.

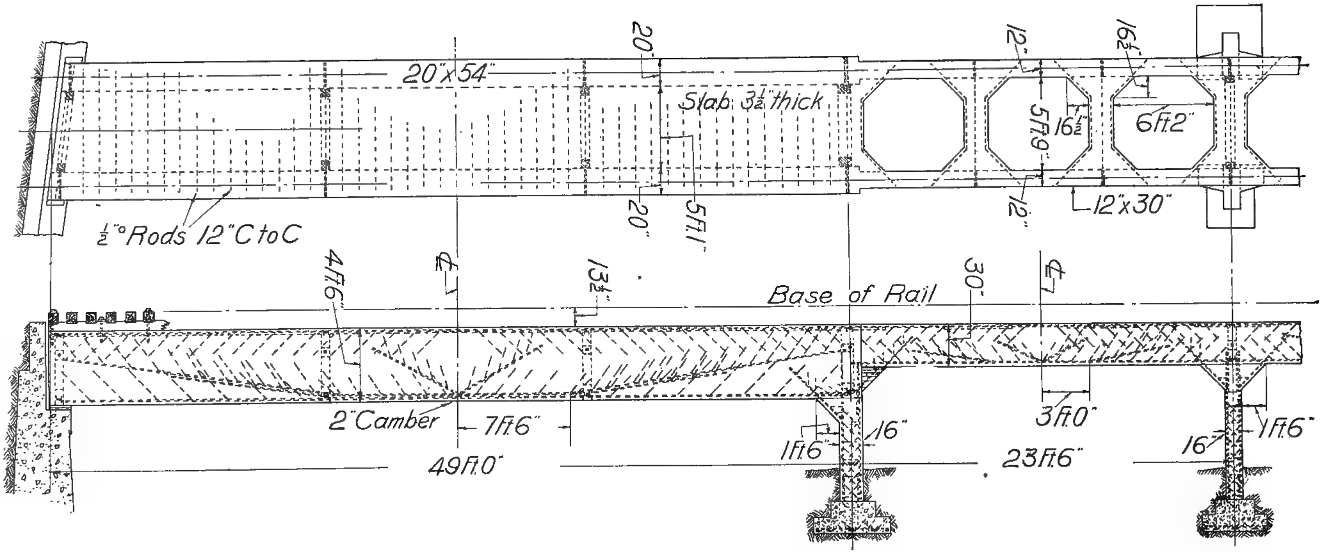


FIG. 21.—PLAN AND ELEVATION OF RICHMOND VIADUCT.

CONCRETE PILE TRESTLES, C., B. & Q. R. R.—These trestles, which replace similar wooden structures, possess a number of features comparatively new to the field of concrete construction. In general, the construction consists of six pile bents spaced 14, 15 or 16 feet center to center, and with an average height of 10 feet. The essential details of design and construction are shown by the drawings in Fig. 21, while the photograph in Fig. 20 shows a typical trestle.

FIG. 22.—CONCRETE PILE TRESTLE, C., B. & Q. R. R.

Two types of piles are used, namely, rectangular cast piles and Chenoweth rolled piles. The cast or molded rectangular piles are made in lengths up to 30 feet, and are 16 inches square at the top with 4-inch chamfers. The reinforcement consists of eight ½-inch bars wired to a spiral coil of wire of varying pitch. The Chenoweth rolled pile, which is the type shown in Fig. 21, is circular in section, 16 inches in diameter, and is reinforced with ½-inch corrugated bars wound spirally with a ½-inch mesh No. 16 wire netting.

The piles are driven vertically by an ordinary railroad pile driver with a 3,000-pound hammer, with cushioned cap, falling 24 feet.

The piles are capped by deep reinforced concrete cross girders, which support the slabs forming the floor or deck.

Each span consists of two reinforced concrete slabs or girders, each slab forming half the width of the floor and having a curb wall to retain the ballast.

For trestles of over 5 or 6 feet spans in length, longitudinal rigidity is obtained by the use of double bents at suitable intervals, consisting of two rows of piles carrying a single cap twice the usual width.

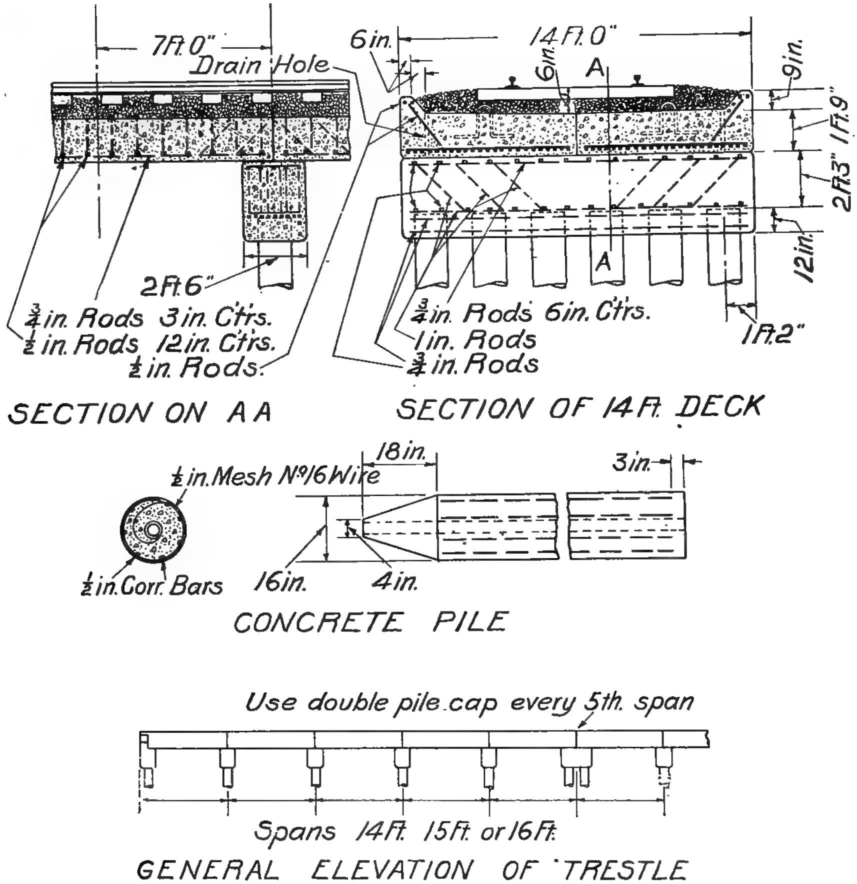


FIG. 21.—PILE TRESTLE, C., B. & Q. R. R.

In the first of these trestles to be built, a solid pier was used in place of the piles and cap at every sixth bent, but the double bent construction is now considered preferable.

The deck slabs are cast in the railway company's yards, and after seasoning about sixty days are carried to the bridge site and placed in a similar manner to the deck girder slabs described on page 41. The ballast and track are laid directly on these slabs.

Different proportions of concrete are used for different parts of the trestle. The concrete for the piles is mixed in the proportions of one part cement to three parts fine screened gravel, while for the caps and girder slabs a mixture of 1:4½ with gravel, or 1:2:4 with sand and stone is used.

In constructing these trestles traffic is not interfered with. The floor of the existing timber trestle is partly dismantled and concrete piles are driven to form bents intermediate with the old timber bents. The forms for the caps are then put in place and filled, the concrete being allowed to set about thirty days. Part of the timber trestle is then torn out by a derrick car or wrecking crane and the girder slabs set in place.

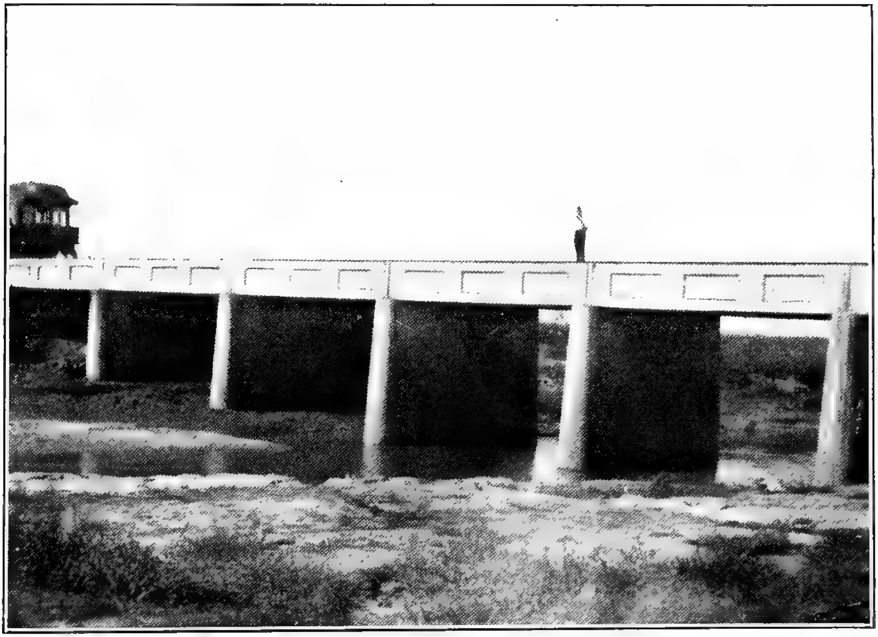


FIG. 22.—PIER TRESTLE, C., B. & Q. R. R.

CONCRETE PIER TRESTLES.—Where longer spans are used and where the trestles cross streams in which floating ice is apt to occur, thin concrete piers are used in preference to the pile bents. The photograph in Fig. 22 shows a typical structure of this type of 25 foot spans. The piers are carried down to footings on a solid foundation or are supported by wooden or concrete piles.

These trestles are designed and constructed by the Engineering Department of the railroad under the supervision of Mr. C. H. Cartlidge, Bridge Engineer.

OVERHEAD HIGHWAY BRIDGES.

Owing to the deteriorating influence of locomotive gases upon the under surface of bridge floors, the construction of overhead highway crossings is one of the greatest problems which railroad engineers are called upon to solve.

There are numerous cases where after a few years steel girders and stringers, even when presumably protected by brick arches, have rusted to one-half their original thickness, thus endangering many lives.

Steel girders, when unprotected, have to be painted very frequently, and, as the accumulated rust formed by the locomotive gases has to be removed, this is a much more expensive operation than under ordinary circumstances. To do away with the high maintenance expense and to overcome the effect of the sulphurous fumes from locomotives, old structures are being encased in concrete and new ones are being built either entirely of reinforced concrete or of structural steel encased in concrete. Bridges thus constructed are absolutely unaffected by ordinary rust, rot or fire, and can be designed economically along artistic lines.

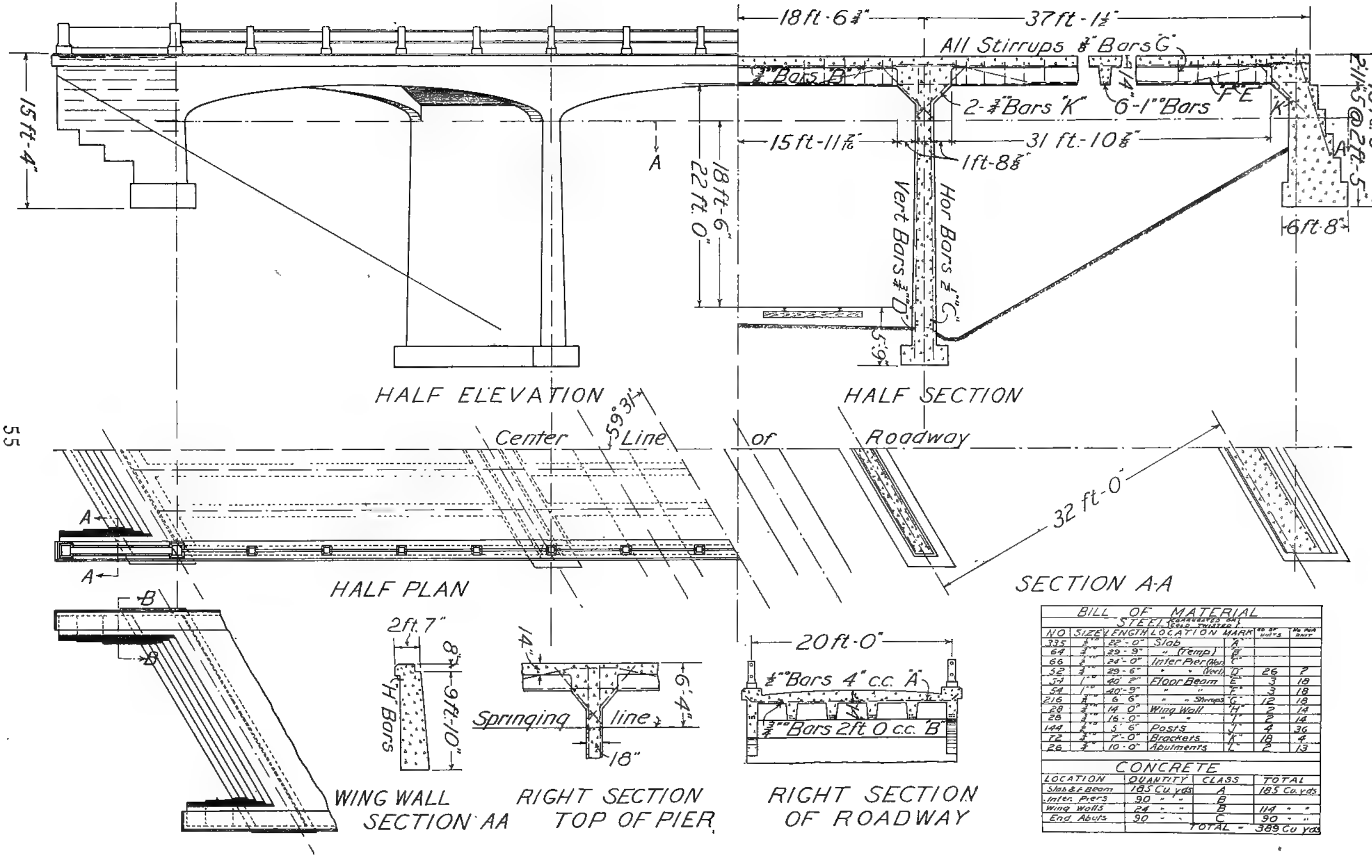
The Blairstown Bridge, described on page 55, is an entirely reinforced concrete structure which is particularly commendable on account of its light and graceful lines, while the First Avenue Viaduct, shown on page 56, is an interesting example of an overhead highway bridge composed of structural steel girders and cross beams encased in concrete.

Other overhead highway bridges are shown among the miscellaneous photographs at the back of the book.

OVERHEAD HIGHWAY BRIDGE, NO. 19.31, D., L. & W. R. R.—As will be seen from the drawings in Fig. 23, which show a half elevation and half section together with details of construction, this bridge consists of two reinforced piers and abutments supporting reinforced girders and floor slab. The two exterior girders are built with the bottoms slightly arched, thus giving the bridge the appearance of being a light arched structure of graceful lines.

The roadway wearing surface is formed by a two inch excess of concrete which is built as a part of the floor slab. A mixture of 1 cement, 2 sand and 4 broken stone was used throughout the structure and the finish obtained by floating the green concrete with water, immediately after removing the forms, and rubbing with wire brushes.

In designing the bridge a ratio of elasticity of 15 was assumed and the concrete was figured at 600 pounds per square inch fiber stress, 500 pounds per square inch compression, and 50 pounds per square inch shear, while the steel was given a tensile stress of 16,000 pounds per square inch and a compressive stress of 7,500 pounds per square inch.



BILL OF MATERIAL

STEEL (Corrugated or Cold Twisted)

NO	SIZE	LENGTH	LOCATION	MARK	No. of Units	No. per Unit
335	½"	22'-0"	Slab	"A"		
64	¾"	29'-9"	" (Temp)	"B"		
66	½"	24'-0"	Inter Pier (Hor)	"C"		
52	¾"	29'-6"	" " (Vert)	"D"	26	2
54	1"	40'-2"	Floor Beam	"E"	3	18
54	1"	40'-9"	" "	"F"	3	18
216	⅜"	6'-6"	" " Stirrups	"G"	12	18
28	¾"	14'-0"	Wing Wall	"H"	2	14
28	¾"	16'-0"	" "	"I"	2	14
144	½"	5'-6"	Posts	"J"	4	36
72	¾"	7'-0"	Brackets	"K"	18	4
26	¾"	10'-0"	Abutments	"L"	2	13

CONCRETE

LOCATION	QUANTITY	CLASS	TOTAL
Slab & F Beam	185 Cu yds	A	185 Cu yds
Inter. Piers	90 " "	B	
Wing Walls	24 " "	B	114 " "
End Abuts	90 " "	C	90 " "
		TOTAL -	389 Cu yds

FIG. 23.—HALF ELEVATION, HALF SECTION, OVERHEAD HIGHWAY BRIDGE, NO. 19.31, D., L. & W. R. R.

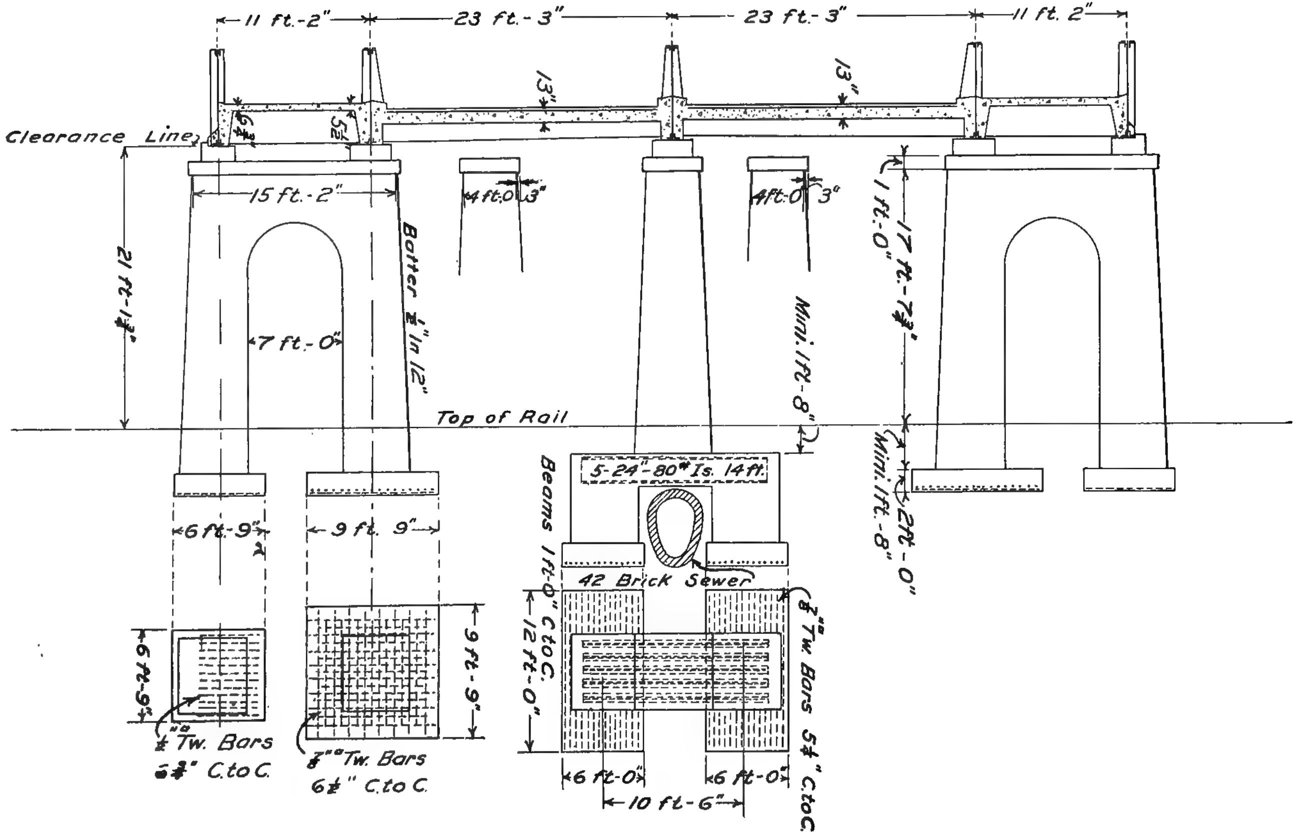


FIG.—24. CROSS SECTION, FIRST AVENUE VIADUCT, L. I. R. R

The bridge, which was constructed in 1909, was designed by the engineering department of the Delaware, Lackawanna and Western R. R., under the supervision of Mr. Lincoln Bush, Chief Engineer, with Mr. B. H. Davis, Assistant Engineer, in charge of masonry design, and F. L. Wheaton, Engineer of Construction, in charge of work in the field.

FIRST AVENUE VIADUCT, L. I. R. R.—This viaduct, 788 feet long, carries First Avenue over the tracks of the Long Island Railroad at Bay Ridge, Long Island. It is 68 feet 10 inches wide, and, as will be seen from Fig. 24, showing a cross section of the viaduct, is divided by the main girders

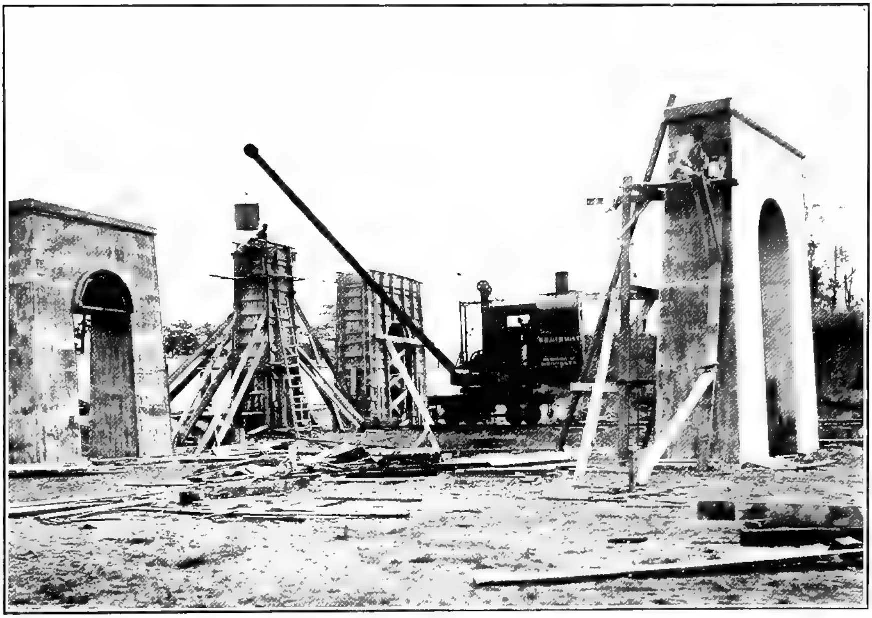


FIG. 25.—FILLING PIER FORMS, FIRST AVENUE VIADUCT.

into two roadways 23 feet 3 inches wide and two sidewalks 11 feet 2 inches wide.

The main girders, which are supported for about half the viaduct on concrete piers, and the remainder of the distance on steel columns and girders, are riveted steel plate girders encased in concrete to a level a little above the roadway and sidewalk. The drawings in Fig. 24 show the manner in which these girders are encased, with details of the bolster protection, and the photograph in Fig. 26 gives a view of the encased girders from below. Fig. 24, mentioned above, gives the general dimensions and essential features of design

FIG. 26.—STEEL GIRDERS ENCASED IN CONCRETE, FIRST AVENUE VIADUCT, L. I. R. R.

of the piers and footings, while the photograph in Fig. 25 is a view taken of them during construction and shows the forms in place and the method of depositing the concrete.

The floor system, the details of which are shown in Fig. 27 (see below), consists of 24 inch 80 pound I-cross beams, 11 feet on centers, entirely encased in concrete, carrying a reinforced concrete floor slab. Twisted rods are used as reinforcement.

The concrete for the piers was mixed in the proportions of 1 part Atlas Portland Cement to 3 parts sand to 5 parts 1½ inch broken stone, and for the other parts of the structure, in the proportions of 1:2:4 with ¾ inch broken stone.

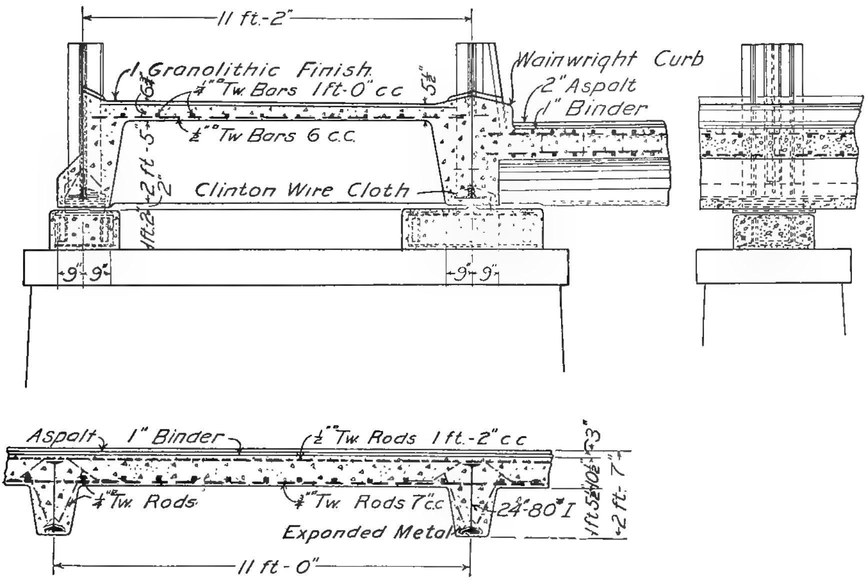


FIG. 27.—DETAILS OF FLOOR CONSTRUCTION, FIRST AVENUE VIADUCT.

Before the concrete of the sidewalk slabs had time to set, a granolithic finish 1 inch thick consisting of 1 part cement to 2 parts trap rock screenings was applied and worked until it became an integral part of the concrete and had a dense and smooth surface.

The pavement for the roadways consists of a 1-inch binder course with a 2-inch wearing surface of asphalt.

By using hangers suspended from the bottom flanges of the cross beams, the forms for the floor slabs and haunches around the bottom flanges of the

steel beams were supported without the use of shoring. Fig. 28 shows this method of construction in detail.

The forms for both piers and floors were treated with car journal oil. Immediately after removing the pier forms, which was on an average about 48 hours after filling, the green concrete was floated with water and rubbed by carborundum bricks.

The construction plant consisted of a 5-ton locomotive crane, a ½ cubic yard mixer, two 24-inch gauge cars carrying two ¼ cubic yard buckets and ordinary iron barrows.

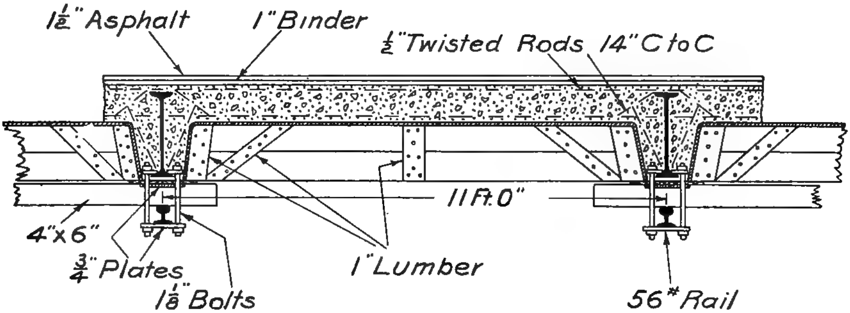


FIG. 28.—FORMS FOR FLOOR SLABS.

The viaduct was designed by the engineering department of the Bay Ridge Improvement Company under the supervision of Mr. L. V. Morris, Chief Engineer, and the concrete work was done by W. H. Gahagan, contracting engineer, of Brooklyn, N. Y., during the fall of 1908 and the winter and spring of 1909.

BRIDGE FLOORS.

Since railroad engineers came to the conclusion a few years ago that the most satisfactory form of bridge floor was a ballasted solid floor, a great many types of wooden and steel floors have been tried. The best of these floors have been very expensive, and while satisfactory for a limited time have proved comparatively short lived.

A number of railroads throughout the country have designed bridge floors, using reinforced concrete in the form of a slab, that have given absolute satisfaction. The reinforced concrete slab usually rests either directly upon the top flange of the girders when used for a deck bridge, or upon floor beams and

girders when used on a through bridge. Both types are illustrated, the former by Fig. 29, and the latter by Fig. 31.

A reinforced concrete bridge floor of considerable proportions,—being in reality a railway yard supported on plate girders—which has given marked satisfaction during the period it has been under traffic, is described on page 62.

C., B. & Q. R. R. BRIDGE FLOORS.—Fig. 29 shows the cross section, including construction forms, of a reinforced slab of trough section used by

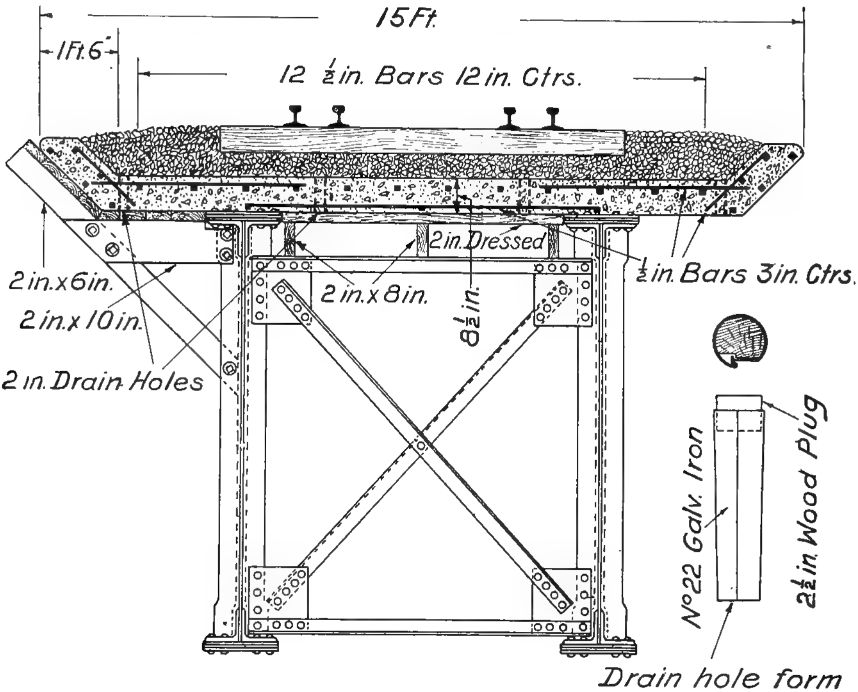


FIG. 29.—CROSS SECTION, DECK GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

the Chicago, Burlington & Quincy R. R. for deck bridges. The photograph in Fig. 30 shows a typical deck bridge floor.

The concrete slab, which is 8½ inches thick, has the outer edges inclined upward at an angle of 30 degrees to make flanges 9 inches deep which retain the standard ballast, the cross ties being placed in the usual manner.

Before putting in the ballast, the top of the deck is painted with tar paint composed of one part oil, four parts cement and sixteen parts tar. Drip pipes are placed in such a position as to keep the drip clear of the iron structure.

As will be seen from the cross section in Fig. 29, the top lateral system and the top angles of the sway brace frames are lowered clear of the top flange angles of the girders to allow the forms for the concrete to be set with greater ease and to be supported on the transverse frames and lateral angles. The outstanding flanges of the vertical web stiffener angles in the girders are punched for connecting bolts to the 2 by 6 inch knee braces of the concrete forms.

FIG. 30.—DECK GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

Fig. 31 shows a typical floor of a through-girder bridge. The reinforced slab rests upon the floor beams and extends up to form curb walls against the girder, enclosing the gusset plates. The slab is 4½ inches thick and is reinforced transversely with ½-inch corrugated bars 6 inches apart and longitudinally with ½-inch bars 1 foot apart. These floors are designed by the engineering department of the railroad under the supervision of Mr. C. H. Cartlidge, Bridge Engineer.

REINFORCED CONCRETE BRIDGE FLOORS, D., L. & W. R. R.—This mammoth bridge floor, 81 by 349 feet, containing 26,269 square feet of floor space is shown in detail in Fig. 33. The concrete is mixed in the pro-

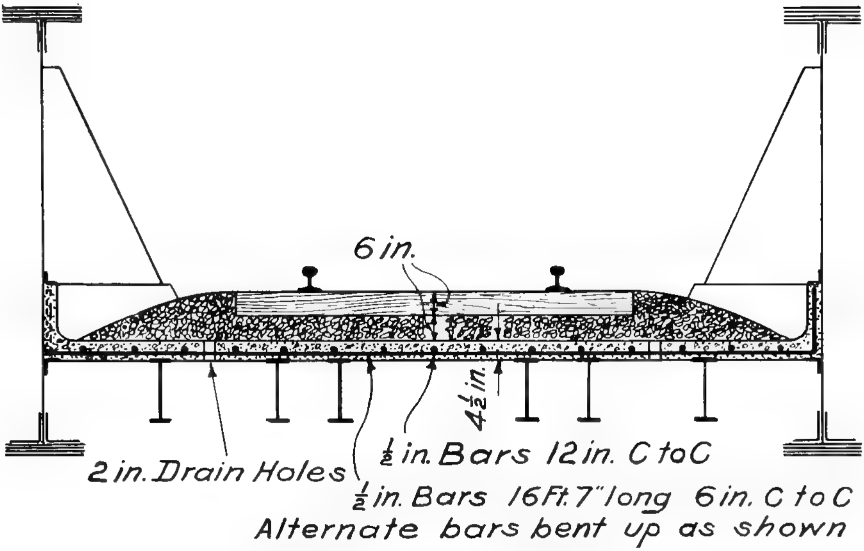


FIG. 31.—CROSS SECTION, THROUGH-GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

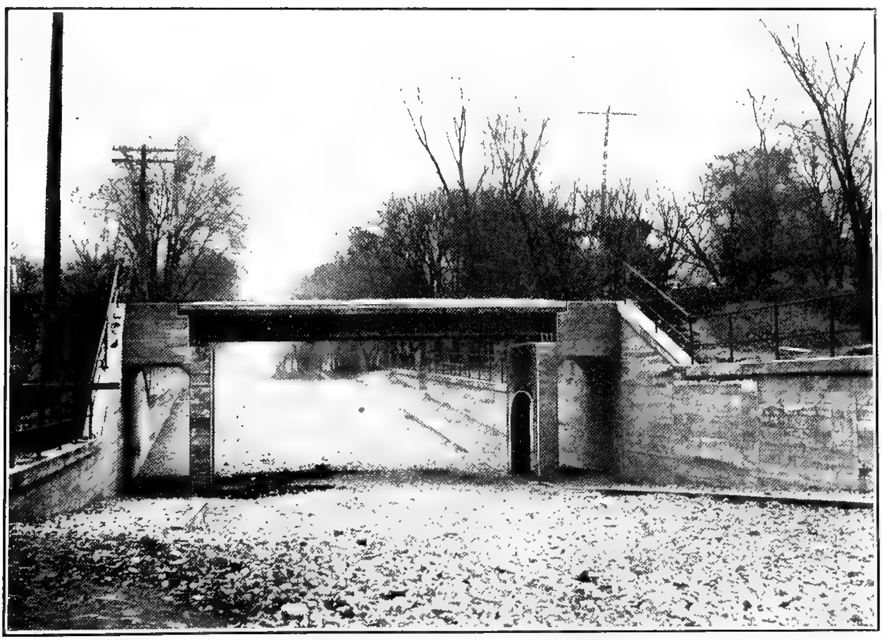


FIG. 32—DECK GIRDER BRIDGE FLOOR, C., B. & Q. R. R.

portions of 1 part Portland cement, 2 parts clean sharp sand and 4 parts 1½ inch broken stone. The top layer, which acts as waterproofing, consists of a 1-inch coating of mortar composed of 1 part Portland cement to 2½ parts sand troweled smooth on top. After this layer had thoroughly set the entire surface was given a heavy coat of pure cement grout.

The floor slab is designed so that switches and cross overs may be made anywhere.

In the construction of the floor, it was found that the economy involved as to material and labor resulted in a saving of from 30 to 40 per cent from the cost of steel channel floor for the same purpose. A square 10 ft. by 10 ft. contains 3,704 cubic yards of concrete and 718.4 pounds of steel, while a standard channel floor composed of 15-inch channels protected by 4 inches of concrete would contain 1,234 cubic yards of concrete and 2,640 pounds of steel.

This floor was designed by the engineering department of the railroad under the supervision of Mr. Lincoln Bush, chief engineer, and Mr. B. H. Davis, assistant engineer in charge of masonry design.

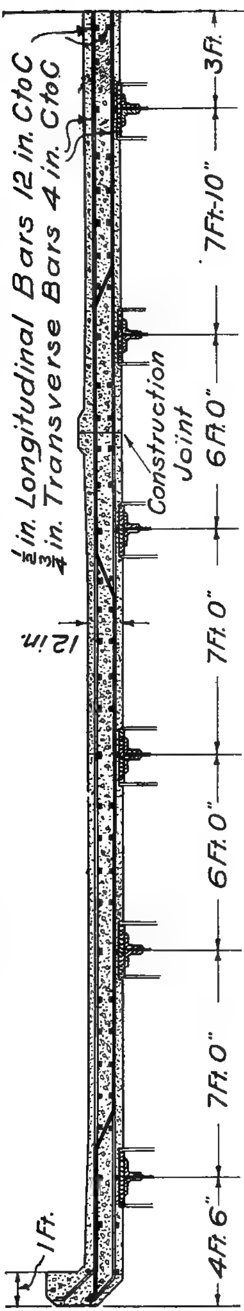


FIG. 33.—HALF-SECTION, BRIDGE FLOOR, D., L. & W. R. R.

CHAPTER IV.

CULVERTS.

Concrete is used to advantage in the construction of all classes of culverts from the small pipe to the large reinforced arch and box types.

On account of its greater simplicity and the less expensive abutments required, the reinforced flat top culvert, with abutments of reinforced concrete, is more economical for short spans than the arch type.

The variation in the designs of the different railroads, together with the fact that none appears entirely satisfactory, has led to the making of special

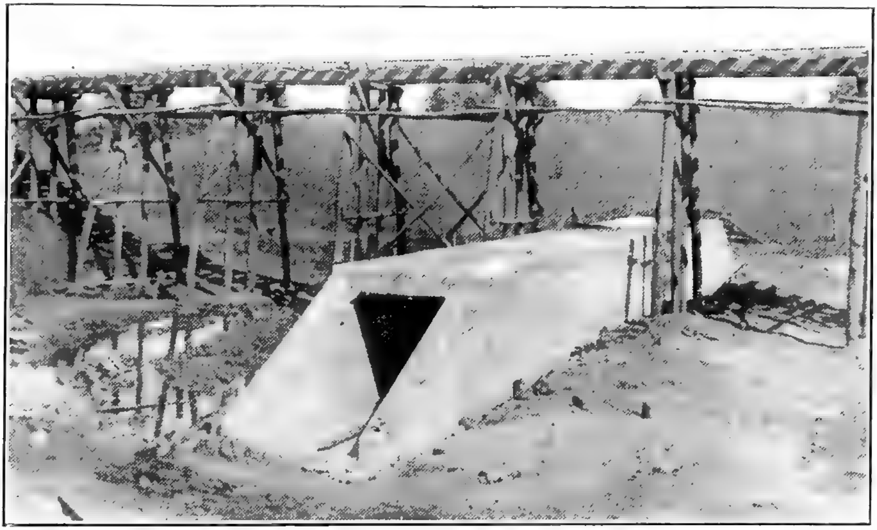
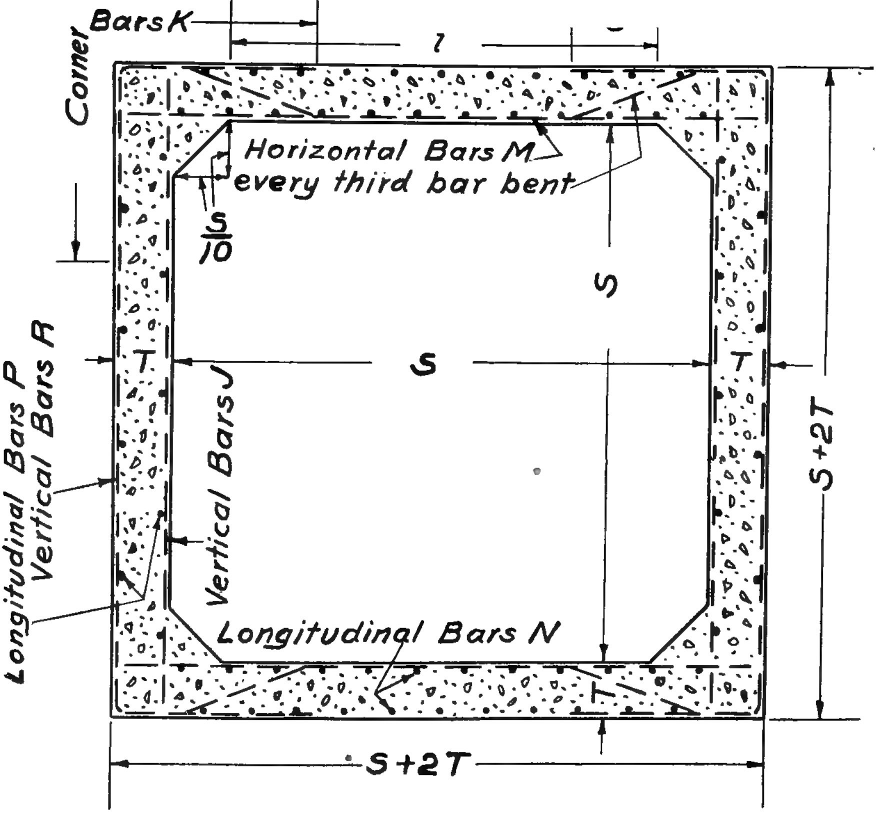


FIG. 34.—5 FT. x 7 FT. BOX CULVERT, C., B. & Q. R. R.

designs for this book. The drawing in Fig. 35 with the accompanying original table give the requisite dimensions for reinforced culverts of 4, 6, 8, 10, 12, 14, 16, 18 and 20 foot spans.

As an aid to the design of concrete arch culverts, without reinforcement, a committee of the American Railway Engineering and Maintenance of Way Association submitted to that association in 1908 a composite design embodying a combination of details of construction of plain concrete-arch culverts with the necessary dimensions, selected from the standards of railroads in the United States and Canada, and for this data the reader is referred to Bulletin No. 105 of that Society.



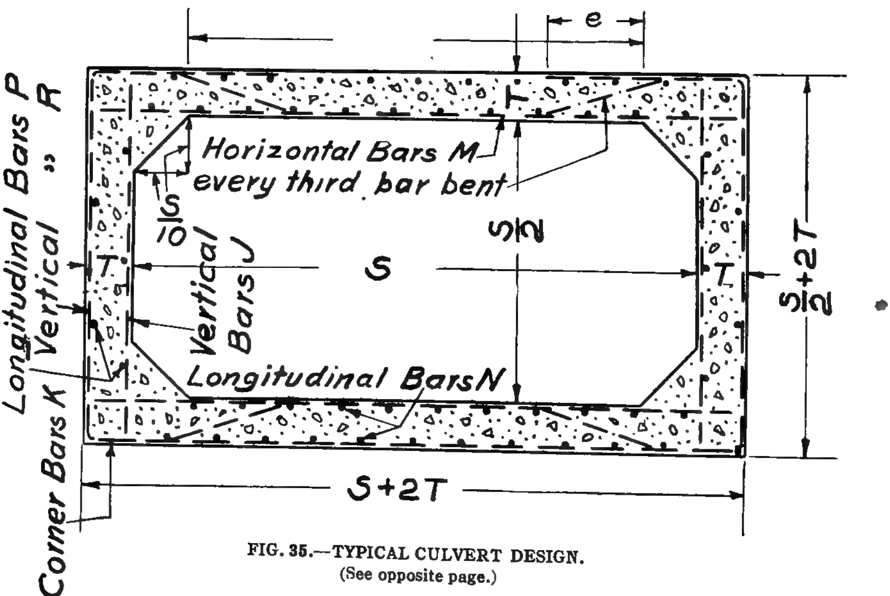


FIG. 35.—TYPICAL CULVERT DESIGN.
(See opposite page.)

DIMENSIONS AND REINFORCEMENT FOR BOX CULVERTS

Square Culverts

Item	Span	Thickness of Wall	Horizontal Walls							Vertical Walls					
			Horizontal Bars M		Corner Bars K			Longitudinal Bars N		Vertical Bars R		Vertical Bars J		Longitudinal Bars P	
	S	T	Size	Spacing	Size	Spacing	L'gth e	Size	Spacing	Size	Spacing	Size	Spacing	Size	Spacing
	ft.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1	4	8	½	6	½	12	At least 50 diam. for plain and 36 diam. for deformed bars.	½	18	½	24	⅜	6	½	24
2	6	8½	¾	8	¾	16		½	18	¾	32	½	8	½	24
3	8	10½	¾	6	¾	12		½	16	¾	24	½	6	½	24
4	10	12½	⅞	7	⅞	14		½	16	⅞	28	½	7	½	20
5	12	14½	⅞	6	⅞	12		½	14	⅞	24	⅝	12	½	20
6	14	17½	1	6¼	1	12		½	14	1	24	¾	11	½	20
7	16	19½	1	5¾	1	11½		½	14	1	23	⅞	11½	½	16
8	18	21½	1⅛	6½	1⅛	13		½	12	1	26	1⅛	13	½	16
9	20	23½	1⅛	5½	1⅛	11		½	12	1	22	1⅛	11	½	16

Oblong Culverts

Item	Span	Thickness of Walls	Horizontal Walls							Vertical Walls					
			Horizontal Bars M		Corner Bars K			Longitudinal Bars N		Vertical Bars R		Vertical Bars J		Longitudinal Bars P	
	S	T	Size	Spacing	Size	Spacing	L'gth e	Size	Spacing	Size	Spacing	Size	Spacing	Size	Spacing
	ft.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
2	6	8	¾	9½	¾	12	At least 50 diam. for plain and 36 diam. for deformed bars.	½	18	¾	12	⅜	12	½	24
3	8	10	¾	6½	¾	13		½	18	¾	13	½	22	½	24
4	10	11½	¾	5¾	¾	7¼		½	16	¾	7¼	½	20	½	20
5	12	13½	⅞	6½	⅞	8¼		½	16	⅞	8¼	½	18	½	20
6	14	16	1	7	1	9		½	14	1	9	½	16	½	20
7	16	17½	1	6¼	1	8		½	14	1	8	½	14	½	16
8	18	19½	1	5½	1	7¼		½	12	1	7¼	½	12	½	16
9	20	21½	1	5	1	6½		½	12	1	6½	½	10	½	16

NOTE—The culverts are designed for following stresses:
Compression in concrete, **650** lb. per sq. in. Tension in steel, **16,000** lb. per sq. in. The weight of earth is taken as **100** lb. per cu. ft. The live load is based on Cooper's standard loading, E 40. The effect of vibration is provided for by increasing the moments due to dead load **50** per cent. All bars are figured as round.

DIMENSION AND REINFORCEMENT FOR CULVERTS FROM 4 TO 20 SPAN.
(See Fig. 35, page 66).

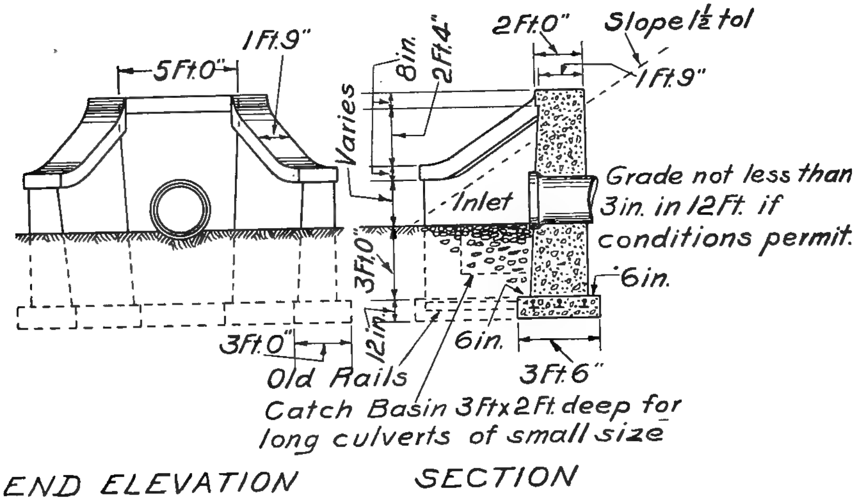


FIG. 36.—STANDARD PIPE CULVERT, WING TYPE, N. Y. C. & H. R. R. R.

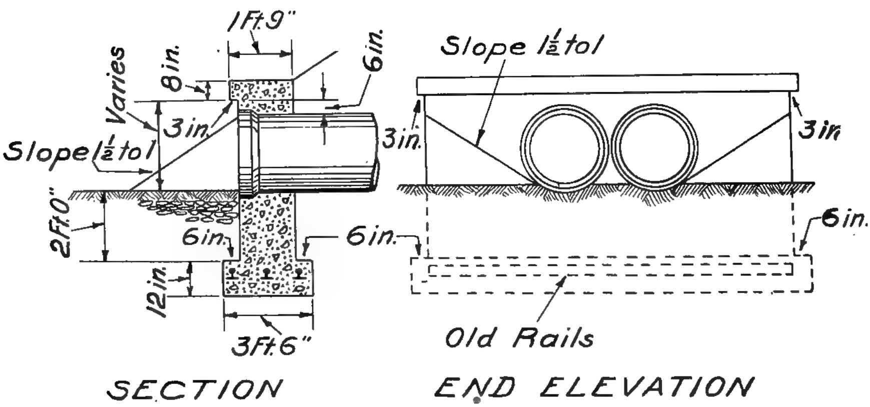


FIG. 37.—STANDARD PIPE CULVERT, STRAIGHT TYPE, N. Y. C. & H. R. R. R.

STANDARD PIPE CULVERTS, N. Y. C. & H. R. R. R.—Fig. 36 shows the standard pipe culvert of the wing type and Fig. 37 the standard pipe culvert of the straight type of the New York Central & Hudson River Railroad. In both types the footings of the end walls are composed of 1:4:7½ concrete, the main body of the walls of 1:3:6 concrete, while the copings are mixed in the proportions of 1:2:4.

STANDARD 3-FOOT ARCH CULVERT, D., L. & W. R. R.—In Fig. 38 is shown a cross-section of the standard 3-foot semicircular arch culvert for 75-feet fills on the Delaware, Lackawanna & Western Railroad. As will be seen from the cross-section, the invert is reinforced with 3/4-inch bars, 12 inches on centers transversely, and 2 feet on centers longitudinally, while the arch itself is reinforced in a longitudinal direction with 3/4-inch bars 18 inches on centers. In case rock or shale is found, the invert reinforcement is left out, and the concrete in the invert reduced to a thickness of one foot throughout. In the body of the culvert there are 0.628 cubic yards of 1:2:4 concrete per linear foot.

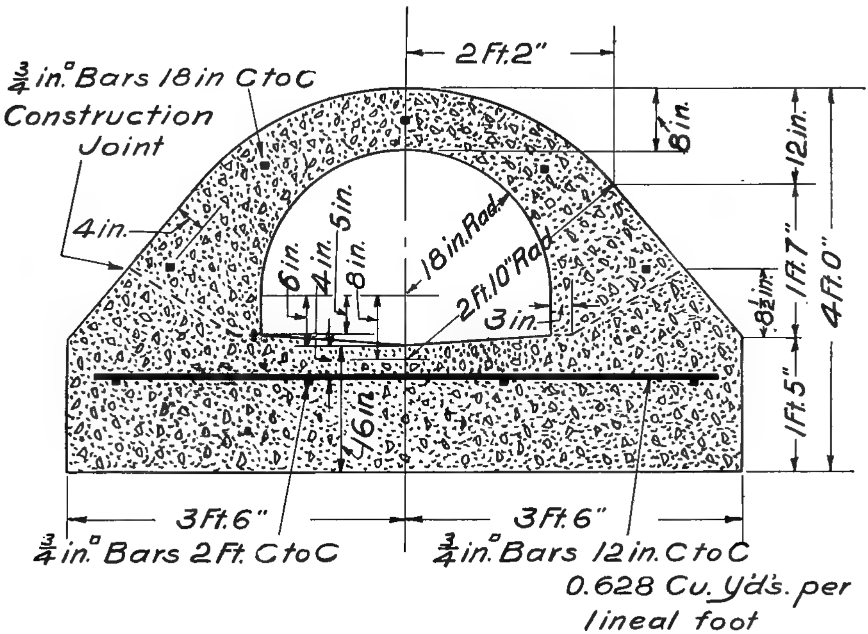


FIG. 38.—CROSS SECTION, 3-FOOT CULVERT, D., L. & W. R. R.

INDIAN CREEK CULVERT, K. C., M. & O. RY.—The drawings in Figs. 39 and 40 give the essential features of design and construction, while the photographs in Figs. 41 and 42 show the finished culvert before and after filling. As will be seen from the drawings, this is a reinforced box culvert 14 by 15 feet and about 250 feet long. An interesting feature in the design of the culvert is the use of reinforced struts spaced 8 feet on centers instead of a solid concrete invert.

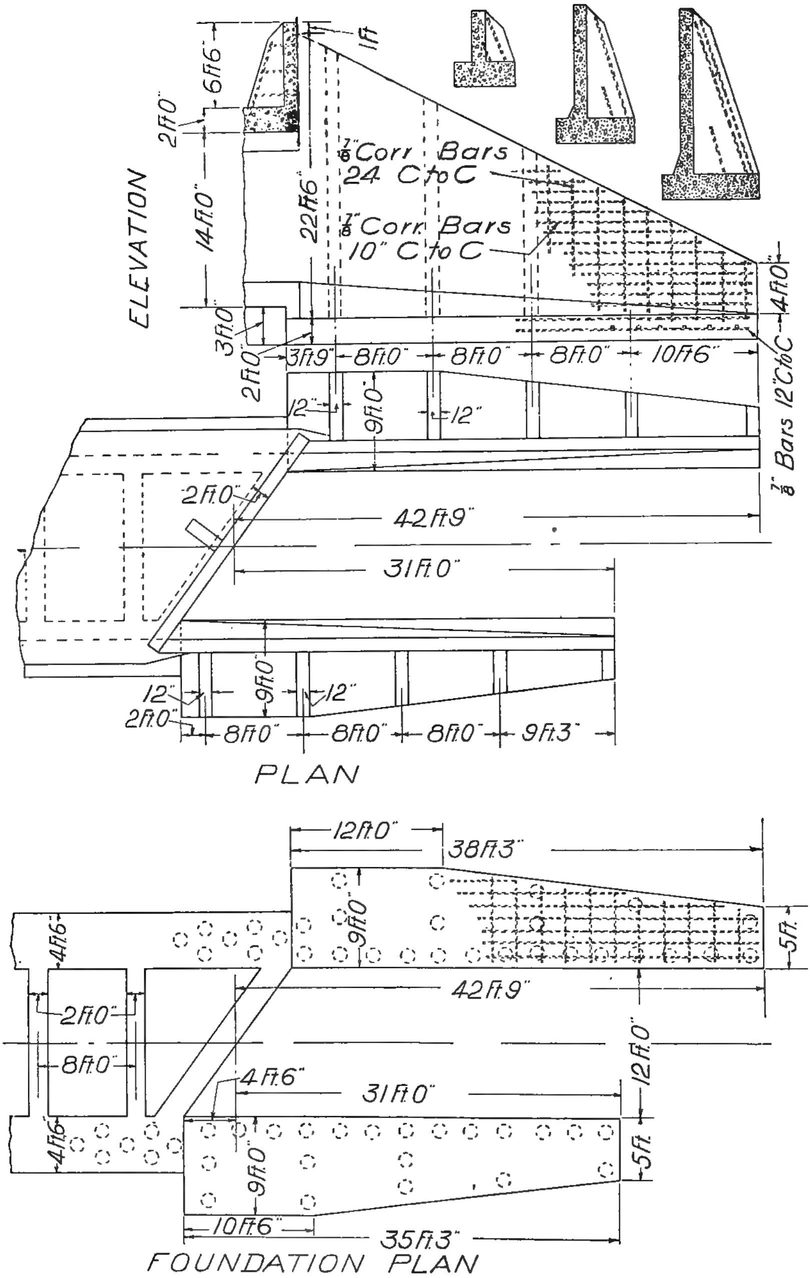


FIG. 39.—PLAN AND ELEVATION, INDIAN CREEK CULVERT.

In the construction of the culvert, the concrete was mixed in the proportions of 1 part cement to 3 parts Kansas River sand to 5 parts crushed limestone, passing a 2-inch ring and freed from dust by screening. The mixing was done by a No. 1 Rotary mixer. The forms were constructed of 1-inch lumber with 2 by 6-inch studs 12 inches on centers. All excavation and pile-driving was performed and the reinforcing bars furnished by the railroad company, who also bore one-half the cost of keeping the foundations dry while the forms were being built and the concrete placed.

The following figures* give the unit cost to the contractor and the unit

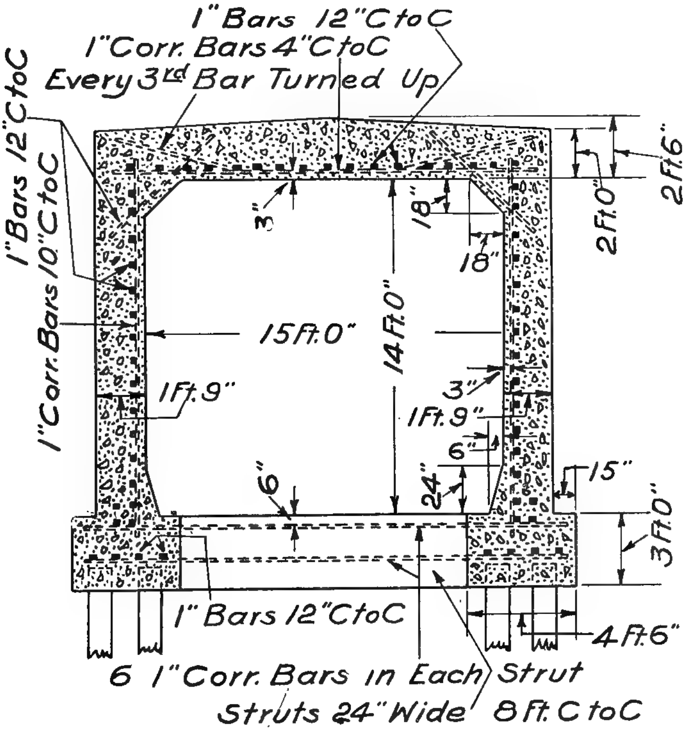


FIG. 40.—CROSS SECTION, INDIAN CREEK CULVERT.

cost to the railroad company, who let the contract on the basis of $9.00 per cubic yard. The costs given covered all labor and materials necessary other than the exceptions mentioned above:

*W. W. Colpitts in "Railway Age," Aug 2, 1907, p. 143.

Unit Cost to Contractor.

Cement	$1.37	per cubic yard of concrete
Sand	0.34	" " " " "
Stone	1.10	" " " " "
Labor	2.48	" " " " "
Lumber	0.76	" " " " "
Miscellaneous	0.18	" " " " "
	$6.23	

Unit cost to Railroad.

Excavation, pumping, etc.	$1.84	per cubic yard of concrete
Piles (389) 8,647 linear ft.	2.71	" " " " "
Reinforcing bars, 113,600 lb.	2.56	" " " " "
	$7.11	

Total unit net cost, not including profit.................. $13.34 per cubic yard

FIG. 41.—INDIAN CREEK CULVERT BEFORE FILLING.

The culvert was designed by Mr. W. W. Colpitts, Assistant Chief Engineer of the Kansas City, Mexico & Orient Railway, and was built by Mr. L. J. Smith, General Contractor, of Kansas City, in the fall of 1905.

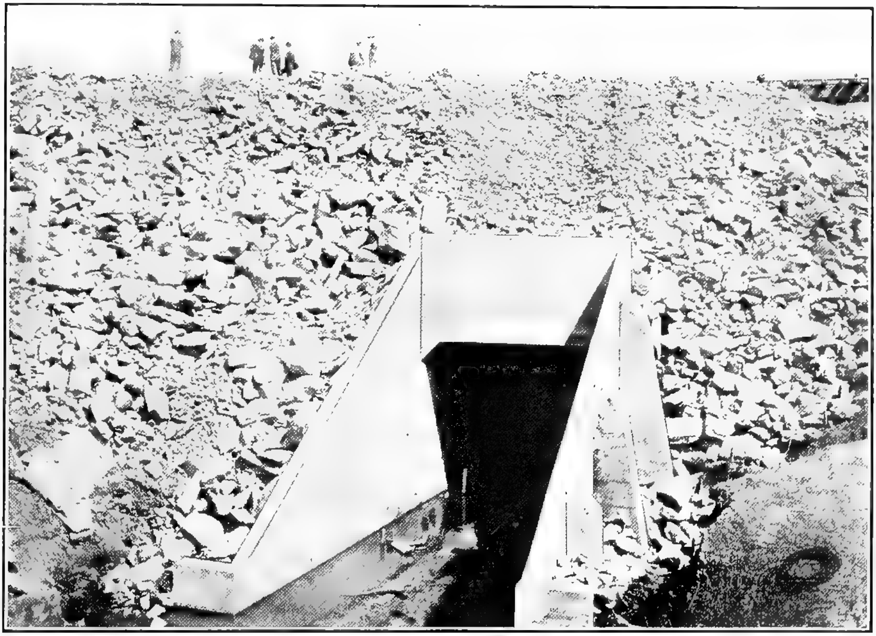


FIG. 42.—INDIAN CREEK CULVERT, K. C., M. & O. RY.

EIGHTEEN FOOT ARCH CULVERT, BANGOR & AROOSTOOK R. R.—The drawing in Fig. 43 and the photograph in Fig. 44, page 74, are of an 18-foot arch culvert on the Bangor & Aroostook R. R., of very simple and at the same time artistic lines. An interesting feature of the design of this culvert is the method employed to protect the soil under the culvert from wash or undertow. This is done by extending the paving, which is of concrete with a minimum thickness of one foot, to the ends of the wing walls, where it makes a vertically downward return to the depth of the bottom of the foundation 5 feet below the bed of the stream or top of paving.

The concrete was mixed in the proportions of one part Atlas Portland Cement to 3 parts sand to 6 parts gravel, and cost, everything included, \$6.42½ per cubic yard.

The culvert was designed and constructed by the engineering department of the Bangor & Aroostook Railroad in 1904 under the supervision of Mr. Moses Burpee, Chief Engineer.

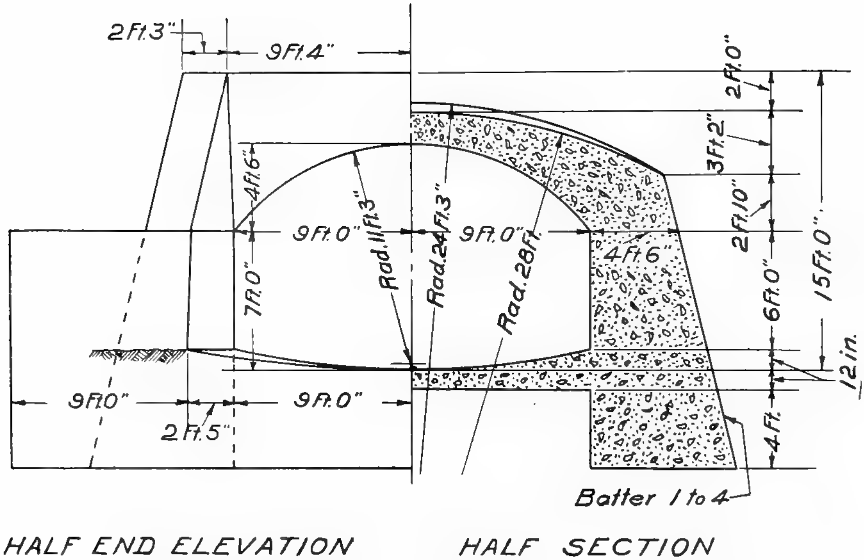


FIG. 43.—CROSS SECTION OF 18-FT. CULVERT, BANGOR & AROOSTOOK R. R.

FIG. 44.—EIGHTEEN FOOT CULVERT, BANGOR & AROOSTOOK R. R.

THIRTY FOOT CULVERT, C., M. & ST. P. RY.—This culvert, which is shown by the photograph in Fig. 45, is of interest owing to the fact that it serves as a footing for trestle bents as well as a culvert. As will be seen from the accompanying picture, footings are built upon the back of the arch on which two of the trestle bents rest. The culvert, which is near Farson, Iowa, was designed and built by the Engineering Department of the Chicago, Milwaukee and St. Paul Railway, under the supervision of Mr. C. F. Loweth, Engineer and Superintendent of Bridges and Buildings, in 1908.

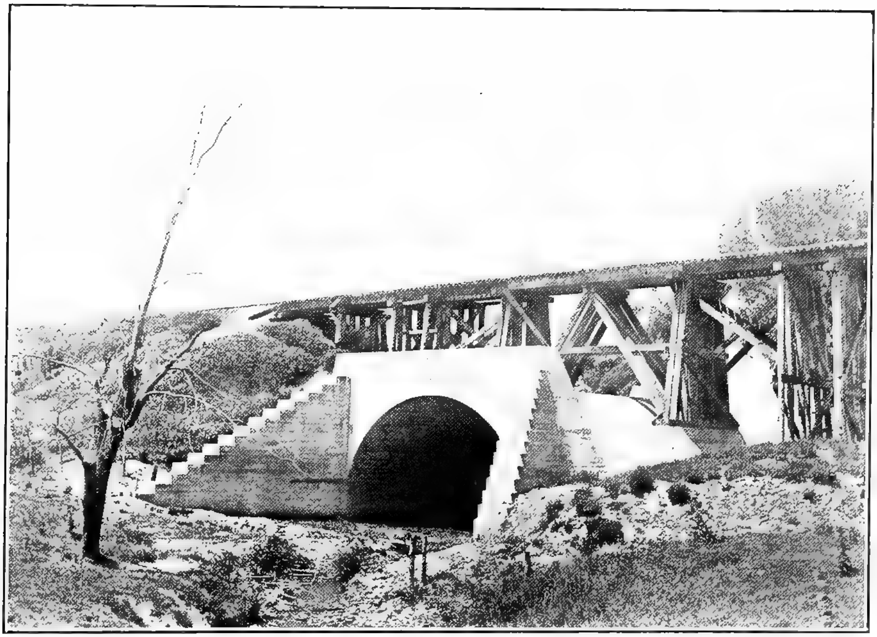


FIG. 45.—THIRTY FOOT CULVERT, C., M. & ST. P. RY.

HORSESHOE CULVERT.—The photograph in Fig. 46, page 76, is of special interest, as it shows a rather unique and very efficient form of heading for culverts where the slope of the embankment is not particularly steep. Instead of perpendicular end walls, a horseshoe heading is formed by cutting the barrel of the culvert to conform to the slope of the fill and by forming a shoulder over the crown to hold the toe of the slope. The culvert is at Runnells, Iowa, and was designed and built by the N. M. Stark Bridge Company of Des Moines, Iowa.

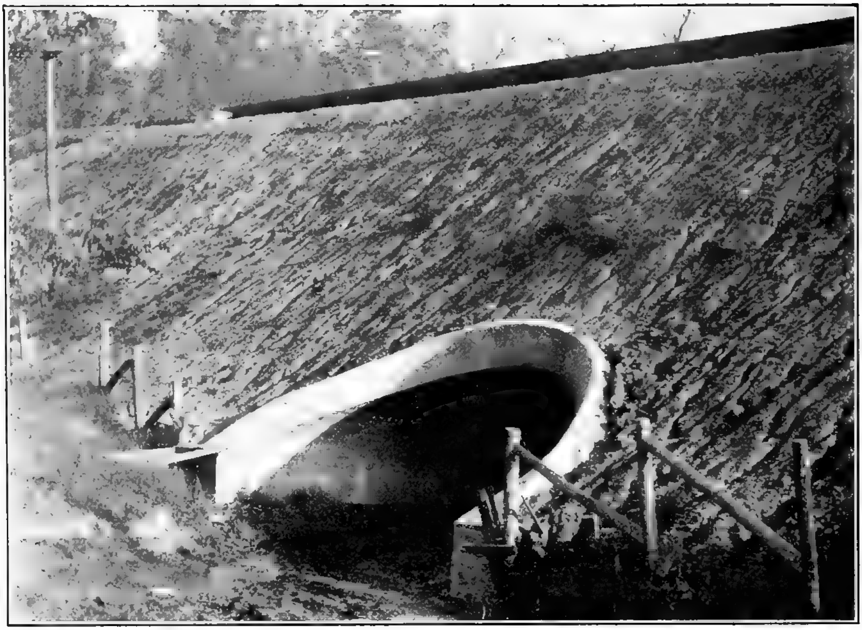


FIG. 46.—HORSESHOE CULVERT, RUNNELLS, IOWA.

FIG. 47.—DOUBLE ARCH CULVERTS, ILL. CENTRAL R. R.

CHAPTER V.

PIERS AND ABUTMENTS.

PIERS.

Concrete is employed for bridge piers either as filling for ashlar or cut masonry, or for the entire pier, in which case it may be of either plain or reinforced concrete. When of plain concrete, the sizes and general proportions are practically the same as for stone piers, the quantity of masonry used for the two not differing materially. If reinforced concrete is used, there may be quite a saving of concrete with a corresponding reduction in the cost of the

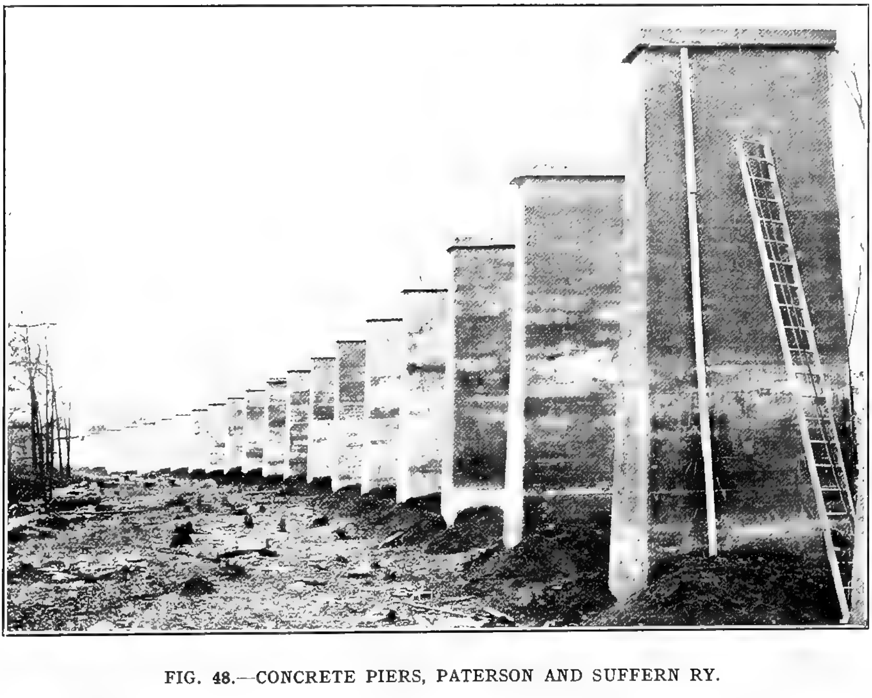


FIG. 48.—CONCRETE PIERS, PATERSON AND SUFFERN RY.

structure. This is obtained either by reducing the size of the pier or by using the ordinary size of pier and making it hollow with reinforced walls, in which case the open space is either filled with sand, broken stone or gravel, or if the pier is designed so that it possesses sufficient stability it is left open, thus making a considerable reduction in the load on the foundation. The

top slab forming the coping is designed strong enough to support the loads brought upon it and transmit them to the side and interior walls, which in turn carry the loads to the foundation. Fig. 52 shows the design of a typical reinforced pier.

Concrete is also used very advantageously in raising the grade of old masonry piers, as is very often necessary, an interesting example of which is described on page 79.

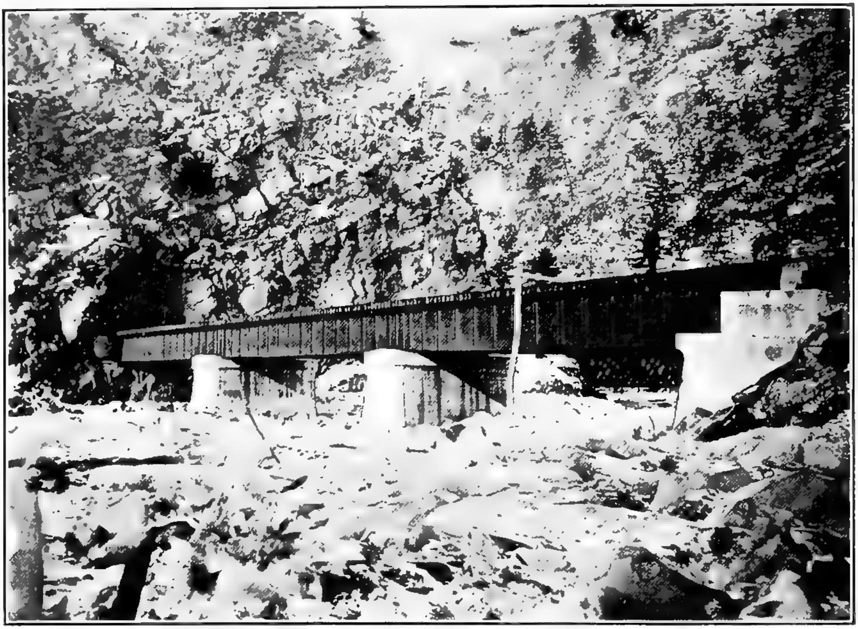


FIG. 49.—CONCRETE PIERS DURING ICE JAM, C. R. R. OF N. J.

STANDARD PIERS, N. Y. C. & H. R. R. R.—The standard pier of this railroad, adapted to any height up to 40 feet, is shown by the drawing in Fig. 50. The width, which is dependent upon the length of span, is as follows:

Spans up to 40 feet width, A, = 4 feet 0 inches
Spans 40 to 60 feet width, A, = 4 feet 6 inches
Spans 60 to 80 feet width, A, = 5 feet 0 inches
Spans 80 to 100 feet width, A, = 5 feet 6 inches
Spans 100 to 125 feet width, A, = 6 feet 0 inches
Spans 125 to 150 feet width, A, = 6 feet 6 inches
Spans 150 to 200 feet width, A, = 7 feet 0 inches
Spans 200 to 250 feet width, A, = 7 feet 6 inches

The foundation which is of 1:3:6 concrete, except where local conditions make stone cheaper, is varied to suit local conditions, but is not less than 4 feet deep unless good rock is found. The pier itself is constructed of 1:3:6 concrete while the coping, which is reinforced with galvanized wire netting or wire cloth is of 1:1:2 concrete, as is the starkweather cap which is two feet above high water. The charts and tables in Fig. 50 give the quantities in these standard piers.

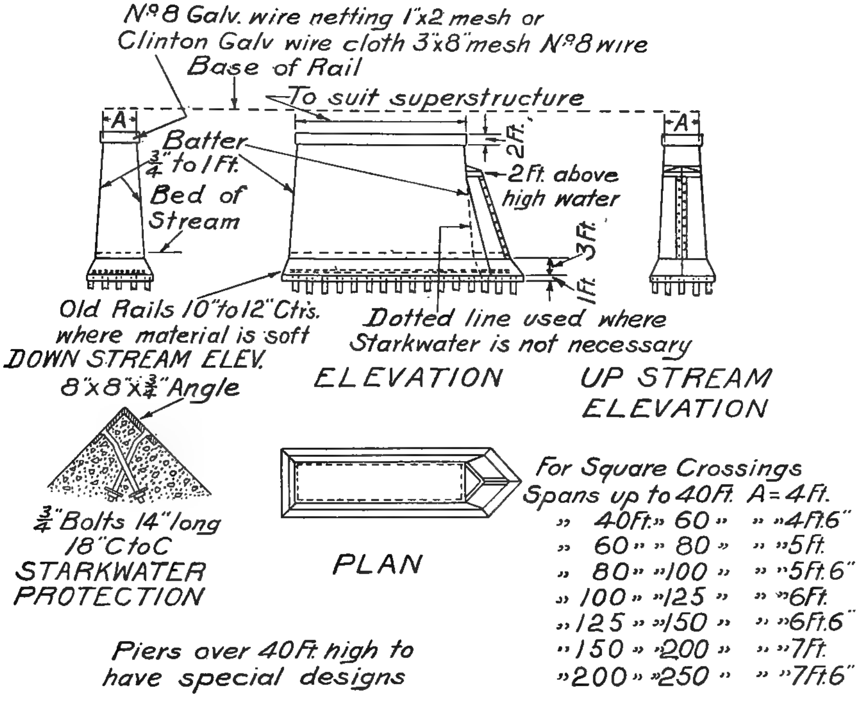


FIG. 50.—STANDARD PIER, N. Y. C. & H. R. R. R.

RAISING GRADE OF OLD MASONRY PIERS.—The photograph in Fig. 51 shows a three span plate girder bridge on the Chicago, Milwaukee and St. Paul Railway which originally rested on piers and square wing abutments of cut stone across which the grade was raised 7½ feet by means of concrete. The girders were raised to grade and the concrete built in place, the rounded ends being formed by means of steel shells held in place by rods which were left in the concrete to give additional strength to the piers. A short span was added at either end of the bridge to take the slope and a rectangular concrete pier of the proper height to bring the masonry up to grade was built on each abutment.

FIG. 51.—RAISING GRADE OF OLD MASONRY PIERS, C., M. & ST. P. RY.

REINFORCED PIER, K. C., M. & O. RY.—In Fig. 52 is shown the design of a standard reinforced concrete pier of the Kansas City, Mexico & Orient Ry.

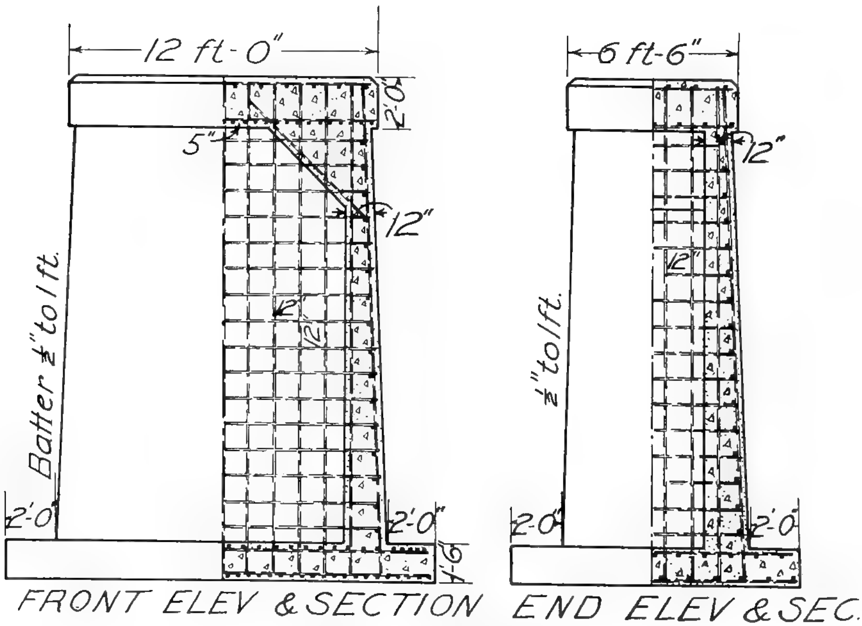


FIG. 52.—STANDARD REINFORCED CONCRETE PIER, K. C., M. & O. RY.

ABUTMENTS

PLAIN ABUTMENTS. Abutments for bridges can be designed of either plain or reinforced concrete. When plain concrete is used the general details are essentially the same as those employed for stone abutments.* The Van Cortlandt Avenue abutments on the N. Y. C. & H. R. R. R., described on page 83 and shown in plan, elevation and section in Fig. 53, are fine examples of this type, not only as to details of construction, but also on account of the architectural treatment of the design.

REINFORCED ABUTMENTS. By using reinforced concrete there is generally a considerable saving in materials which in some instances has been so great as to reduce the cost as much as 40 per cent.

The general features of design and method of reinforcing will be understood from a study of the drawings of the Third Street abutment, K. C., M. & O. Ry., shown in Fig. 56, page 85. It will be seen that the construction, with the exception of the bridge seat and supporting buttresses, closely resembles that of reinforced buttressed retaining walls described in Chapter VI.

The bridge seat consists of a heavy reinforced concrete slab extending over the tops of the supporting buttresses, thus securely knitting the structure together.

These supporting buttresses are located directly under the bridge girders, thus eliminating bending in the slab forming the bridge seat. In designing the buttresses the width must be taken at least equal to that of the bed plate.

In order to resist the overturning moment, vertical bars are placed in the back and extend through the base hooking under the horizontal bars in the bottom. A sufficient number of horizontal bars are placed in the buttresses as shown in Fig. 56, so as to transfer the total load from the face wall to the buttresses without depending upon the tensile strength of the concrete. The diagonal shear in the buttresses is taken care of by the diagonal rods which hook under the bottom bars in the rear of the base and over the longitudinal bars in the face wall.

A face wall, heavy enough to resist the earth pressure and live load transferred through the earth, is placed in front of, and constructed monolithic with, the buttresses, the two being firmly tied together by means of the reinforcing bars with hooked ends. This face wall is continued beyond the bridge seats to form wings, and is supported by buttresses at intervals of about 8 feet.

At the back of the bridge seat there is a parapet wall forming the back or mud wall, as in a stone abutment, which is provided with returns at the ends

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*The design of abutments for arches is treated in Taylor & Thompson's "Concrete Plain and Reinforced," Second Edition, 1909, and in Baker's "Masonry Construction."

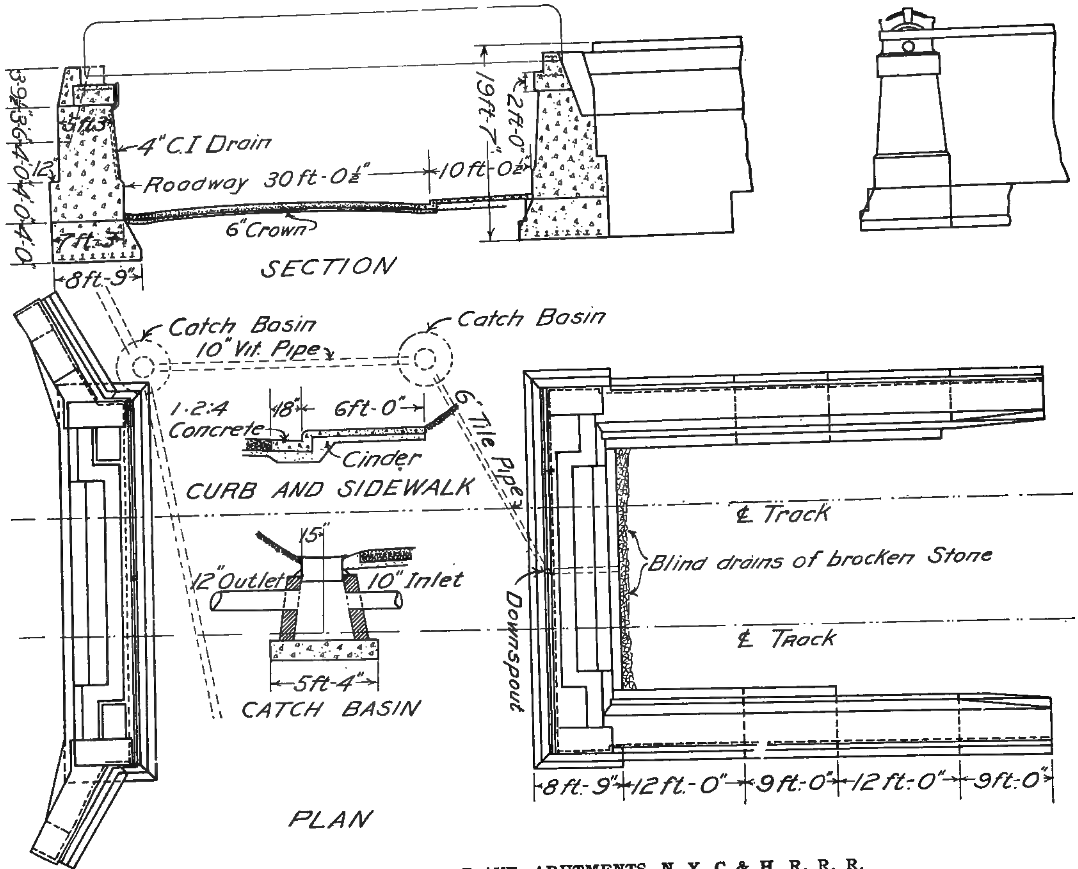


FIG. 53.—VAN CORTLANDT AVE. ABUTMENTS, N. Y. C. & H. R. R. R.

to the face walls and is supported by buttresses similarly to the front wall, and in addition by the vertical bars extending into the bridge seat.

The base consists of a rectangular slab sufficiently reinforced to distribute over the foundation the load transmitted by the buttresses under the bridge seat. Usually, as is the case in the design mentioned above, the width of the base is not taken less than one-half the height of the abutment. To minimize the eccentricity of the load, the base extends about two feet beyond the face wall.

FIG. 54.—VAN CORTLANDT AVE. ABUTMENTS, N. Y. C. & H. R. R. R.

VAN CORTLANDT AVE. ABUTMENTS, N. Y. C. & H. R. R. R. These abutments, which were designed and constructed by the engineering forces of the New York Central Railroad during the fall of 1904, are noteworthy examples of the adaptability of concrete to architectural treatment in structures of this nature, which are frequently crude to the extreme.

The drawings in Fig. 53 show the essential features of design and construction, while the photograph in Fig. 54 gives an idea of the artistic effect which is derived from the moulded pylons and the graceful lines of the wing walls.

In the construction of the abutments four different proportions of

Atlas cement, sand and broken stone were used as follows: Footings 1:4:7½; main wall and wing walls, 1:3:6; bridge seats and pylons, 1:1:2, and copings, 1:2:4.

Old rails with joints staggered and bolted together with two angle bars were laid in the footings 12 inches on centers and 6 inches from the bottom. The bridge seats were reinforced with Clinton Galvanized Wire Cloth, 3 by 8 inch mesh No. 10 wire.

Each abutment is provided with a 4-inch cast iron down spout which is hidden in a 6 by 8 inch chase in the center of the face of the wall and connects with a 6-inch tile drain on one side and discharges into the gutter on the other.

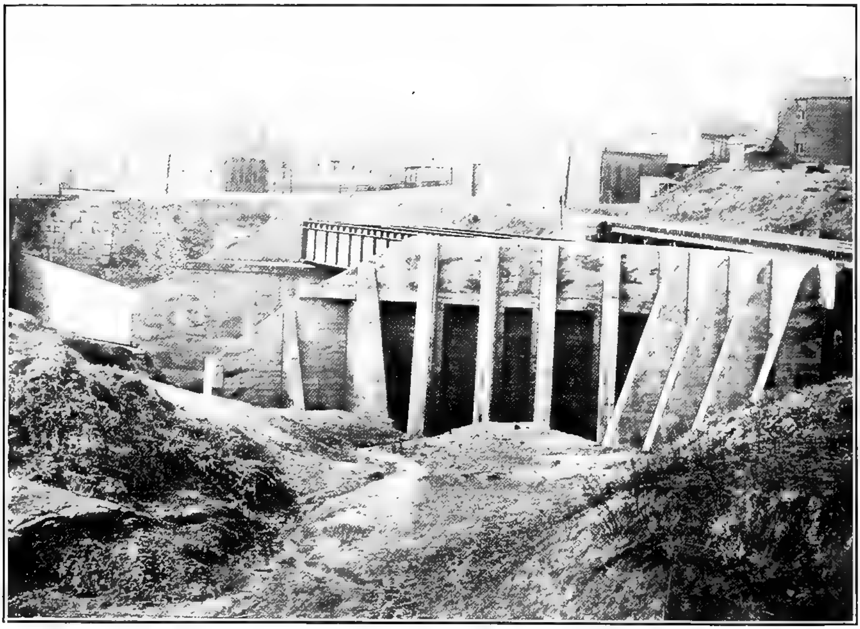


FIG. 55.—THIRD STREET ABUTMENTS, K. C., M. & O. RY.

THIRD STREET ABUTMENTS, K. C., M. & O. RY. These reinforced concrete abutments are on the Kansas City Outer Belt and Electric Railroad, which furnishes an entrance into Kansas City and terminal facilities for the Kansas City, Mexico and Orient Railway, and were designed by Mr. W. Colpitts, Assistant Chief Engineer of the road, and built by Mr. L. J. Smith, general contractor, of Kansas City, in the fall of 1906.

The general dimensions, arrangement of reinforcing and principal features of design are shown clearly on the drawings in Fig. 56, while the photograph in Fig. 55 shows the finished structure.

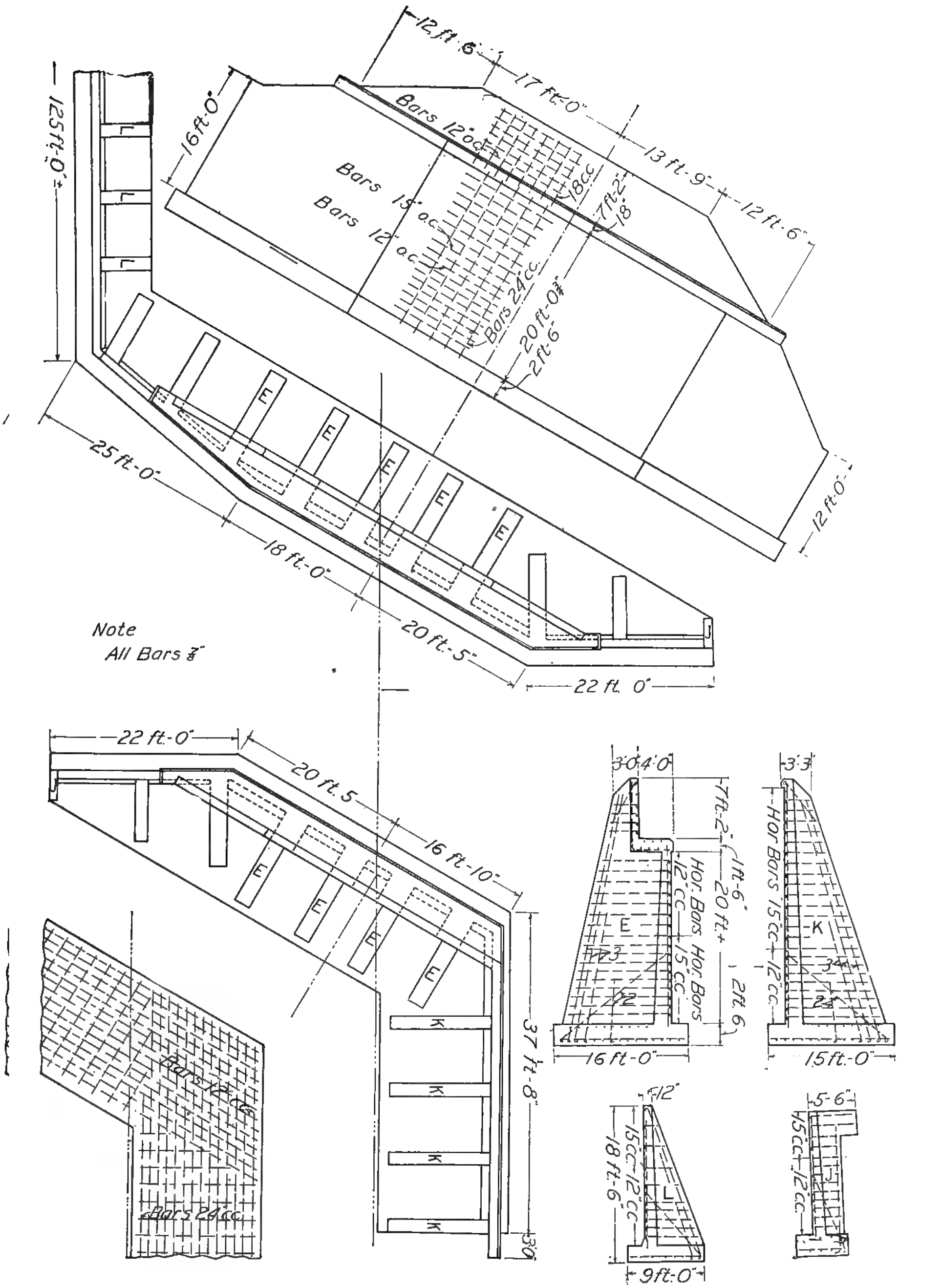


FIG. 56.—THIRD STREET ABUTMENTS, K. C., M. & O. RY.

With the exception of the bridge seats, which are of 1:2:4, all the concrete was mixed in the proportion of 1 part Portland cement to 3 parts Kansas river sand to 5 parts crushed limestone, passing a 2-inch ring and freed from dust by screening.

Seven-eighths-inch corrugated bars were used for reinforcing throughout the abutments and adjoining retaining walls. All bars were lapped 3 feet with joints broken. The supporting piles extend 6 inches into the base slab and were covered with three inches of concrete before the reinforcing bars were put in place. In both abutments and retaining walls the face walls were trenched six inches into the base slab.

The forms were constructed of 1-inch lumber with 2 by 6 inch studs 12 inches on centers and the concrete was mixed by a No. 1 Rotary Mixer.

All excavation and pile driving was done and the reinforcing bars furnished by the railroad company, who also bore one-half the cost of keeping the foundations dry while the forms were being built and the concrete placed.

The following figures* give the unit cost to the contractor and the unit cost to the railroad company who let the contract on the basis of $9 per cubic yard, which covered all labor and materials necessary except the items under "unit cost to railroad."

*Unit cost to contractor:

Cement	$1.78	per	cubic	yard	concrete
Sand	0.35	"	"	"	"
Stone	1.35	"	"	"	"
Lumber	0.74	"	"	"	"
Labor	2.75	"	"	"	"
Miscellaneous	0.16	"	"	"	"
	$7.13	"	"	"	"

Unit cost to railroad:

Excavation (total)	$3.80	per	cubic	yard	concrete
Piles (214) 5,228 lin. ft.	1.84	"	"	"	"
Reinforcing bars	1.82	"	"	"	"
	$7.46	"	"	"	"
Total unit cost, not including profit	$14.59	"	"	"	"

CHAPTER VI.

RETAINING WALLS.

The use of both plain and reinforced concrete for retaining wall construction in track elevation and depression work has become general throughout the country. The plain concrete walls are designed of gravity section, that is, they are made sufficiently heavy to prevent sliding or overturning by their own weight. Reinforced walls consist either of a thin vertical wall attached to a horizontal base and braced either by counterforts on the back or by buttresses on the front side, or they are designed as cantilevers, in which case the wall is attached to a spreading base, the whole section being in the form of an inverted T.

Reinforced concrete retaining walls usually are more economical than plain concrete walls, since in the latter type the material cannot be fully utilized because the section must be made heavy enough to prevent overturning by its own weight. In reinforced concrete retaining walls, on the other hand, a part of sustained material is used to prevent overturning, and the section need be made only strong enough to withstand the moments and shears due to the earth pressure. The wall is lighter and exerts smaller pressure on the soil, which with the possibility of extending the base of the wall sometimes enables the constructor to get along with ordinary foundations in cases where for masonry walls piles would have been indispensable. They also admit the use of a more scientific design, since the behavior of reinforced concrete is even better known and more reliable than that of plain concrete.

The common practice among railroad engineers of using arbitrary ratios of width of base to height of walls in designing retaining walls, leads to a neglect of the study of the distribution of the pressure on the foundation. Since it is well established that movements from the original alignment due to unequal settlement from a defect more common than any other, this question is of great importance and each case should be carefully studied and the amount and distribution of the pressure on the bed or foundation determined.

Also, by a careful analytical treatment, the most effective section and the minimum amount of material will be attained, whereas many of the walls thus far designed have embodied a great waste of material with a resulting lack of economy in design.

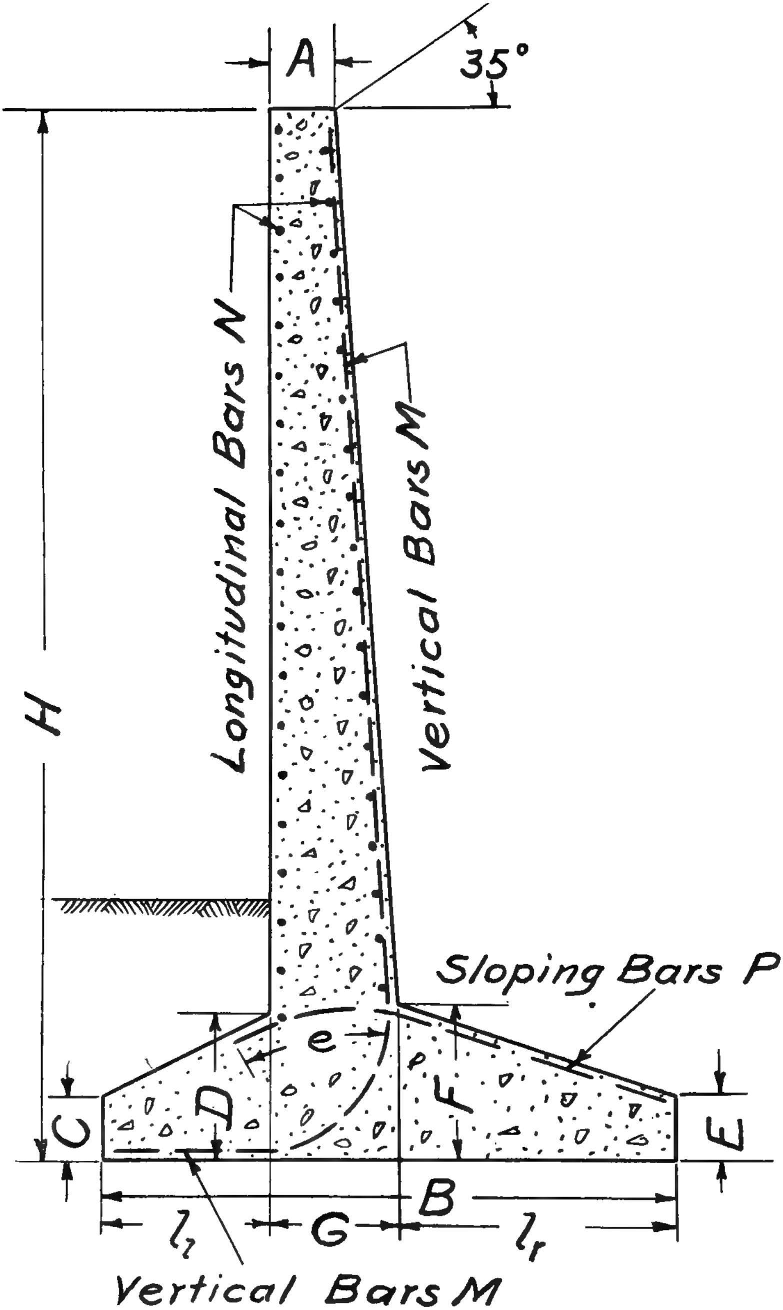


FIG. 57.—DESIGN OF T-SECTION RETAINING WALLS.

DIMENSIONS AND REINFORCEMENT FOR T-TYPE RETAINING WALLS.

Item	Total Height H	Length of Base B	Length of Right Cantilever l_r	Length of Left Cantilever l_l	Upright Beam: Dimensions of Slab: Thickness at Top A	Upright Beam: Dimensions of Slab: Thickness at Bottom G	Reinforcement: Plain Round Bars M: Size	Plain Round Bars M: Spacing	Deformed Square Bars M: Size	Deformed Square Bars M: Spacing	Horizontal Bars N: Size	Horizontal Bars N: Spacing	Left Cantilever: For Round Plain Bars: Thickness at End C	For Round Plain Bars: Max. Thickness D	For Square Deformed Bars: Thickness at End C	For Square Deformed Bars: Max. Thickness D
	ft.	ft.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.
1	8	4	20	18	6	9½	½	4¾	⅜	4¾	½	12	6	12	6	9
2	12	6.5	39	24	8	15½	⅝	4¼	½	5	⅝	9	8	17	8	13½
3	16	8.75	50	31	10	23½	⅞	5½	⅝	5⅜	⅝	9	10	27	10	18
4	20	11	62	39	12	31½	⅞	4	¾	5	⅝	8	12	30	12	23½

Item	Total Height H	Right Cantilever: For Plain Round Bars P: Dimensions of Slab: Thickness at End E	For Plain Round Bars P: Max. Thickness F	For Plain Round Bars P: Size of Round Bars	For Plain Round Bars P: Spacing	For Plain Round Bars P: Length of Imbedment e	For Deformed Square Bars P: Dimensions of Slab: Thickness at End E	For Deformed Square Bars P: Max. Thickness F	For Deformed Square Bars P: Size of Square Bars	For Deformed Square Bars P: Spacing	For Deformed Square Bars P: Length of Imbedment e	Unit Pressure on the Soil: Maximum	Unit Pressure on the Soil: Minimum	Tangent of Angle of the Resultant Pressure with the Vertical
	ft.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	lbs. per sq. ft.	lbs. per sq. ft.	Tang. ϕ
1	8	6	13½	7/16	5	11	6	8¼	⅜	4½	12	2,450	0	0.60
2	12	10	18½	⅝	4¾	20	8	14	⅝	6¼	21	3,700	0	0.59
3	16	12	28½	¾	5	29	10	19½	¾	6¼	24	5,000	0	0.59
4	20	14	35½	⅞	4¼	36	12	29½	⅞	5½	29	6,100	.300	0.59

NOTE 1.—When the maximum unit pressure on the soil given in the table is too excessive, it may be reduced by extending the left cantilever of the footing. Following formula

$$b = \frac{B}{2}\left[-(2+m) + \sqrt{m(m+8)}\right]$$

gives the necessary length of extension, b, of the base, B, to reduce the maximum pressure to $\frac{1}{m}$ of its previous value. The left cantilever should be then re-designed for the new forces acting on it, using the common reinforced concrete beam formulas.

NOTE 2.—In the retaining wall design the following working stresses and conditions are assumed:
Compression in concrete, **500** lb. per sq. in. Tension in steel, **16,000** lb. per sq. in. Bond of plain bars to concrete, **80** lb. per sq. in. Bond of deformed bars to concrete, **120** lb. per sq. in. Shear involving diagonal tension, **40** lb. per sq. in. Angle of internal friction, **35°**; slope of earth above wall **35°**; weight of earth, **100** lb. per cu. ft. All bars are figured as round except the deformed bars as specified.

DIMENSIONS AND REINFORCEMENT FOR T-TYPE RETAINING WALLS.

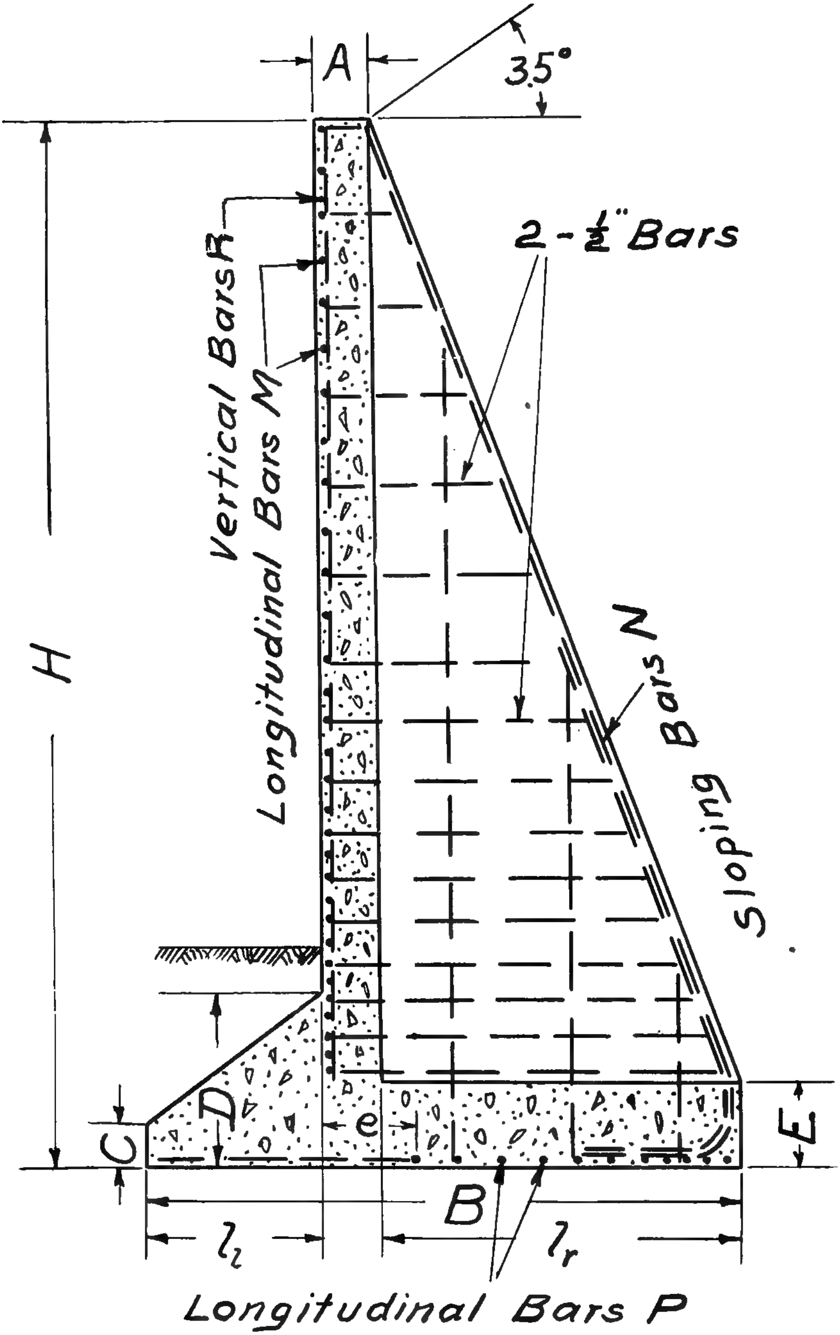


FIG. 58.—DESIGN OF COUNTERFORT TYPE OF RETAINING WALLS

Item	Height of Wall H	Length of Base B	Length of Right Cantilever l_r	Length of Left Cantilever l_l	Left Cantilever of Footing: For Plain Bars: Dimensions of Slab: Thickness at End C	Max. Thickness D	Reinforcement: Size Round	Spacing	Length of Imbedment e	For Deformed Bars: Dimensions of Slab: Thickness at End C	Max. Thickness D	Reinforcement: Size Square	Spacing	Length of Imbedment e	Vertical Slab: Thickness of Slab A	Reinforcement: Size of Bars	Number and Spacing of Bars M
	ft.	ft.	ft.	ft.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	in.	
1	20	11	6.7	3.25	12	34½	¾	4	24	12	23½	¾	5	16	13	⅝	6, 6″ o.c., 4, 10″ o.c. 4, 8″ o.c., balance 12″ o.c.
2	24	13.5	8.3	4	14	48	⅞	4⅜	26	14	31	⅞	5½	26	13½	⅝	8, 5″ o.c., 5, 8″ o.c. 6, 6″, balance 12″ o.c.
3	28	15.5	9.45	4.75	16	57½	1	4½	36	14	39½	1	5¾	30	14	⅝	6, 4″ o.c., 8, 8″ o.c. 12, 6″ o.c., balance 12″ o.c.
4	32	18	11.45	5.33	16	58½	1	4	38	14	41	1	5	32	14½	⅝	8, 4″ o.c., 6, 6″ o.c. 8, 8″, balance 12″ o.c.

Table Continued

Item	Height of Wall H	Horizontal Slab Footing: Thickness E	Reinforcement: Size	Number and Spacing of Bars P	Counterforts: Spacing of Counter forts	Reinforcement: Thickness	Number and Size of Bars N	Length of Imbedment e	Unit Pressure on the Soil: Maximum	Minimum	Tangent of angle of the resultant pressure with the vertical.
	ft.	in.	in.		ft.	in.		in.	lbs. per sq. ft.	lbs. per sq. ft.	Tang. %
1	20	21½	⅞	4, 6″ o.c., 3, 9″ o.c., balance 12″ o.c.	7½	14	1, 1″ bar, 23 ft. long 2, 1″ " 17 " " 3, 1¼″ " 11 " "	50 50 62	6,100	300	0.59
2	24	23½	⅞	5, 5½″ o.c., 3, 9″ o.c., balance, 12″ o.c.	8	16	1, 1¼″ bar, 29 ft. long 2, 1¼″ " 23 " " 1, 1¼″ " 17 " " 2, 1¼″ " 11 " "	62	7,500	000	0.59
3	28	26½	⅞	4, 4¾″ o.c., 5, 9″ o.c., balance, 12″ o.c.	8½	18	2, 1¼″ bars, 33 ft. long 2, 1¼″ " 23 " " 2, 1¼″ " 17 " " 3, 1¼″ " 11 " "	62	8,420	000	0.60
4	32	28½	⅞	5, 4″ o.c., 6, 9″ o.c., balance, 12 o.c.	9	18	2, 1¼″ bars, 37 ft. long 3, 1¼″ " 28 " " 3, 1¼″ " 20 " " 4, 1¼″ " 11 " "	62	8,300	1,100	0.59

NOTE—In the retaining wall design the following working stresses and conditions are assumed:

Compression in concrete, **500** lb. per sq. in. Tension in steel, **16,000** lb. per sq. in. Bond of plain bars to concrete, **80** lb. per sq. in. Bond of deformed bars to concrete, **120** lb. per sq. in. Shear involving diagonal tension, **40** lb. per sq. in. Angle of internal friction, **35°**; slope of earth above wall **35°**; weight of earth, **100** lb. per cu. ft. All bars are figured as round except the deformed bars as specified.

DIMENSIONS AND REINFORCEMENT FOR RETAINING WALLS WITH COUNTERFORTS.

As to which of the two types of reinforced concrete retaining walls is for a specific case the more economical depends upon the height of the wall, the intensity of earth pressure and the relative cost of concrete and steel. As a general thing the construction of the inverted-T type is simpler and the placing of the steel easier, requiring less skilled labor and experience.

The least height at which the counterfort type may be economical has been found by special studies for this chapter to be in general about 18 feet.

In retaining walls of any considerable length it is necessary to provide against shrinkage and temperature cracks.

The general practice for walls of unreinforced concrete is to place contraction joints at intervals of from 30 feet to 50 feet. It is possible to provide enough horizontal reinforcement to so distribute the temperature stresses that the cracks will be very minute and scarcely noticeable. For this 0.3 per cent of horizontal steel based on the vertical section of the wall is sometimes used and this should be placed near the surface and in small sized rods. It is quite common practice to introduce a smaller quantity of horizontal reinforcement and in addition provide occasional contraction joints to allow for movement and to localize any cracking.

In constructing retaining walls it is of the utmost importance that careful attention be given to the earth filling and to its drainage. The drainage is most easily accomplished by filling close to the back of the wall with some porous material such as gravel, crushed stone or cinders and by placing weep holes through the wall at suitable distances apart to carry the water from behind the wall. The distance apart of these weep holes is dependent upon local conditions, and should be decided after careful examination of the ground. The standard retaining wall specifications of a number of railroads call for weep holes not more than 15 feet apart with vertical blind drains extending to the top of the wall.

It is not within the scope of this book to go into a discussion of the various methods of determining the pressure exerted on retaining walls or to give a theoretical treatment of the designs of the different types of walls, but the tables in Figs. 57 and 58 give the necessary dimensions for the T-section and counterfort types of retaining walls for heights and pressures ordinarily met with. These have been prepared especially for this book. For a complete analysis of the subject of concrete retaining walls the reader is referred to Taylor and Thompson's "Concrete, Plain and Reinforced," second edition, 1909, and to "Walls, Bins and Grain Elevators," by Milo S. Ketchum.

In designing the walls given in the tables referred to above, the earth pressure was computed by Rankine's formula for a fill weighing 100 pounds per cubic foot and an angle of repose of 35 degrees. The filling was assumed as sloping behind the wall at the angle of repose.

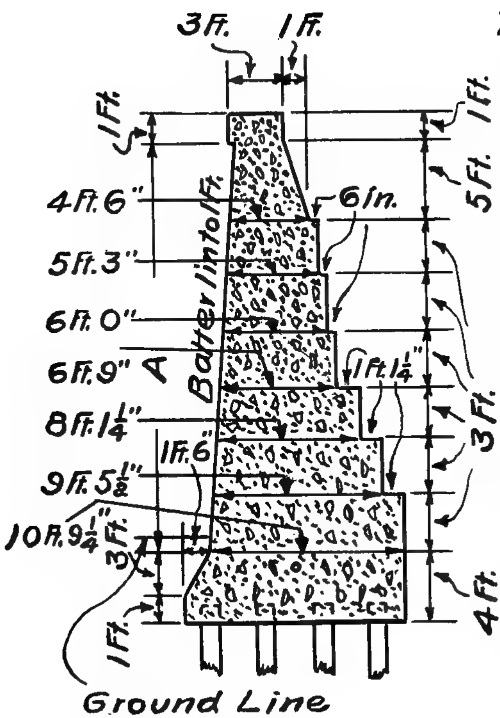
The unit stresses assumed were: Compression in the concrete, 500 pounds per square inch; tension in the steel, 16,000 pounds per square inch; shear in the concrete involving diagonal tension, 40 pounds per square inch; bond, 80 pounds per square inch for plain and 120 pounds per square inch for deformed bars.

FIG. 59.—BRONX IMPROVEMENT RETAINING WALL, N. Y. C. & H. R. R. R.

EXAMPLES OF RETAINING WALLS.

STANDARD GRAVITY RETAINING WALL, N. Y. C. & H. R. R. R. Fig. 60 shows the cross section and table of contents per running foot of this type of wall. The concrete below the ground line is mixed in the proportions of 1:4:7½, from the ground line to the coping, in the proportions of 1:3:6, and for the coping, in the proportions of 1:2:4. Expansion joints filled with one layer of tar paper with the edge ¼-inch back from the face of the masonry are provided every 50 feet. The back filling consists of cinders or other porous material and the drainage is taken care of by 4-inch weep holes not more than 15 feet apart, with vertical blind drains extending to the top of the wall. Along side walls these weep holes are placed 9 feet below the top of the side walls and are piped to the gutter.

The photograph in Fig. 59 is an example of a gravity retaining wall on the Bronx improvement work carried on by the New York Central and Hudson River Railroad.



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Height A	Cu. yds per running ft.		
	Coping	Body Wall	Found. 4 ft deep
5 Ft. 0	0.111	0.671	0.833
6-0	"	0.858	0.920
7-0	"	1.048	0.932
8-0	"	1.241	0.944
9-0	"	1.455	1.032
10-0	"	1.673	1.044
11-0	"	1.894	1.056
12-0	"	2.136	1.143
13-0	"	2.381	1.155
14-0	"	2.630	1.167
15-0	"	2.922	1.343
16-0	"	3.217	1.355
17-0	"	3.516	1.367
18-0	"	3.858	1.544
19-0	"	4.204	1.556
20-0	"	4.553	1.568
21-0	"	4.946	1.744
22-0	"	5.341	1.756
23-0	"	5.740	1.768
24-0	"	6.183	1.946
25-0	"	6.628	1.958
26-0	"	7.078	1.970
27-0	"	7.571	2.146
28-0	"	8.068	2.158
29-0	"	8.567	2.170
30-0	"	9.110	2.346

FIG. 60.—STANDARD GRAVITY RETAINING WALL, N. Y. C. & H R. R. R.

REINFORCED RETAINING WALLS, C., B. & Q. R. R.—Fig. 61 shows the essential features of design and construction of a typical track elevation retaining wall of the Chicago, Burlington and Quincy Railroad, which is in reality a compromise between the plain monolithic and the cantilever types of walls. In designing, no attempt was made to use the full compressive strength of the concrete, as such a condition would have required a much greater amount of reinforcement and at the same time would have developed an excess of strength beyond requirements. Sections at the top of the footing, at the angle in the back of the wall, and at points both above and below this angle were analyzed and the stresses computed by Prof. Howe's formulas and a sufficient amount of reinforcement was provided to take care of the total tensile strength at every point which, however, was very small because of the comparatively heavy section. Owing to the difficulty in constructing reinforced abutments, plain concrete was used; the footings, however, have a reinforced projection in front to increase the bearing area. As a general thing

the walls are supported on piles closely spaced under the toe and more widely apart under the heel. The concrete was mixed in the proportions of 1 part cement to 6 parts pit run gravel.

In Fig. 62 are shown the forms used in constructing these walls, together with the method of bracing and tying down the forms. They comprise a combination of continuous and sectional forms, the sectional portion consisting of

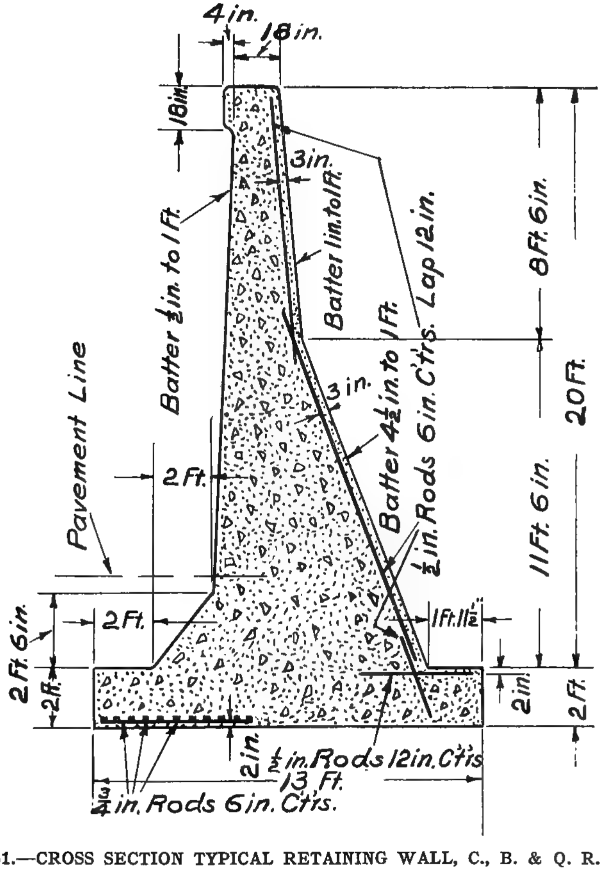

FIG. 61.—CROSS SECTION TYPICAL RETAINING WALL, C., B. & Q. R. R.

studs, coping and bottom forms for the face, and entire sectional forms for the back of the wall.

As the cross section of the wall is such that in filling the concrete showed a tendency to lift the forms off the footing, ½-inch bars were placed in the footing, as shown in Fig. 62, and the forms tied to them with wires. The wall forms are tied together by ¾ rods which pass through pieces of 2-inch scrap

pipe cut to fit loosely between the forms, the ends of the pipes being stuffed with waste to keep the grout from filling them.

In regard to the cost of walls of this type, Mr. C. H. Cartlidge, Bridge Engineer of the C., B. & Q. R. R., under whose supervision, with Mr. L. J. Hotchkiss, Assistant Bridge Engineer, the walls were designed, writes as follows:*

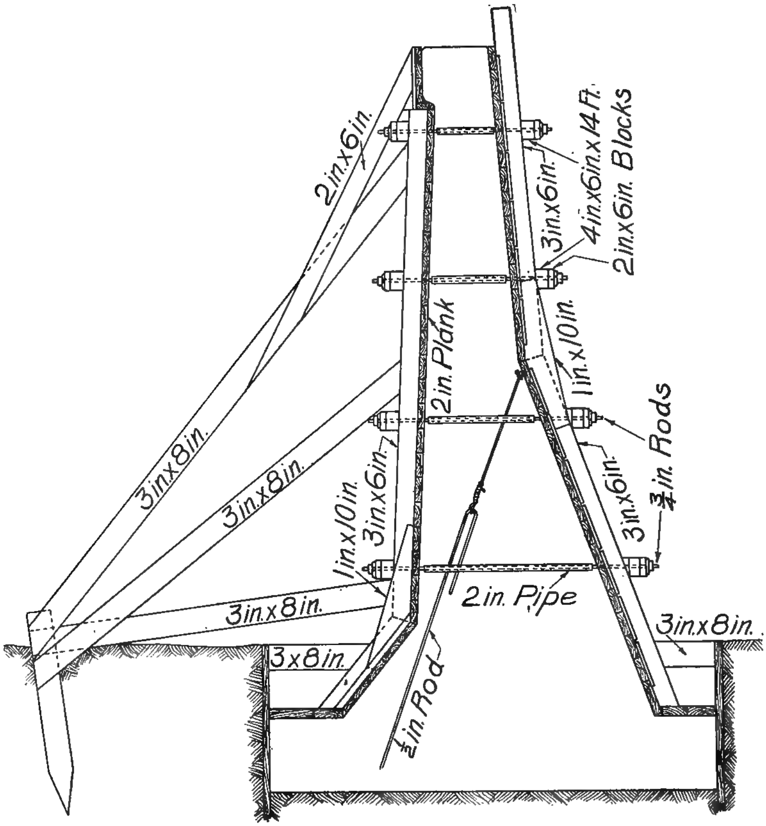

FIG. 62.—FORMS FOR RETAINING WALL, C., B. & Q. R. R.

"This wall (reinforced concrete) will show an economy over a gravity wall of solid concrete. The cost of a large amount of work, including everything, has been a little less than \$9 per yard. For the concrete only, exclusive of excavation and piling, \$6.23 per yard. Our abutments are solid concrete without any reinforcing. These cost us per cubic yard \$5.55, including everything. The high cost per yard of the retaining

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*Bulletin No. 108, p. 426, American Railway Engineering and Maintenance of Way Association.

walls for excavation and piling is, of course, due to the fact that comparatively little concrete is used per yard of excavation. The true comparison, therefore, is between the concrete in the two, being for the retaining walls as stated above, $6.23 and $5.03."

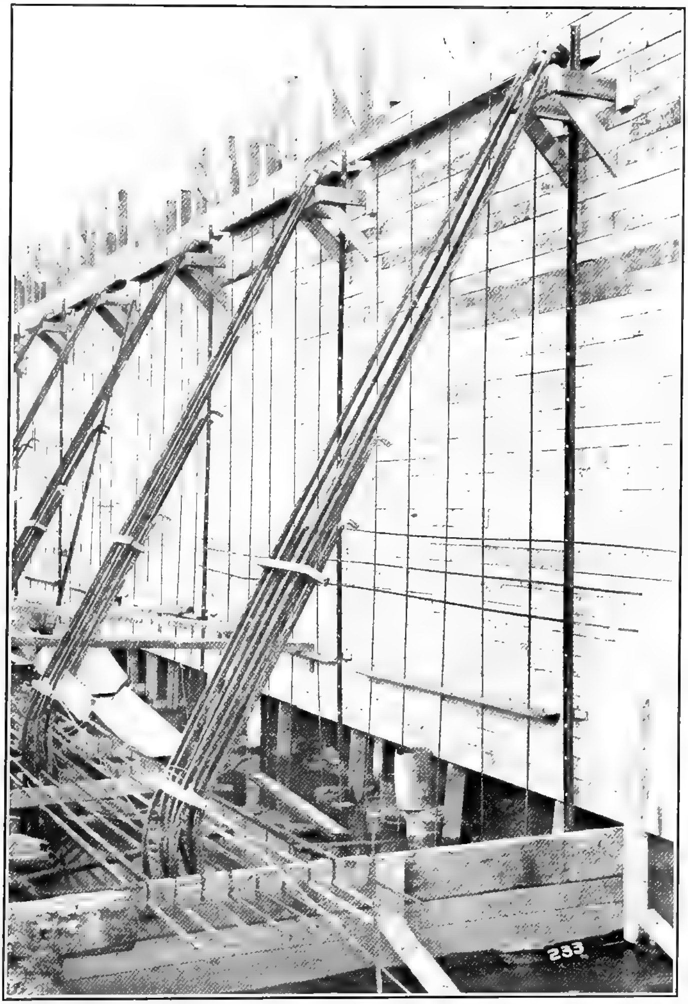

FIG. 63.—REINFORCEMENT IN PLACE, BUFFALO RETAINING WALL.

REINFORCED BUTTRESS RETAINING WALLS, D., L. & W. R. R. The photograph in Fig. 63 shows the method of constructing and reinforcing the counterforts of the retaining wall at Buffalo, New York, while the photograph in Fig. 64 is of the finished wall.

In addition to the retaining walls just described, there are a number of illustrative examples of different types of walls among the miscellaneous photographs at the end of this book.

FIG. 64.—BUFFALO RETAINING WALL, D., L. & W. R. R.

CHAPTER VII.

STATIONS, TRAIN SHEDS AND PLATFORMS.

Railroads throughout the country are adopting the use of concrete in the construction of railway stations of every class, in many cases for the entire structure and in others for integral parts such as foundations, platforms, smoke ducts, stairways, and often for architectural features, such as cornices, belt

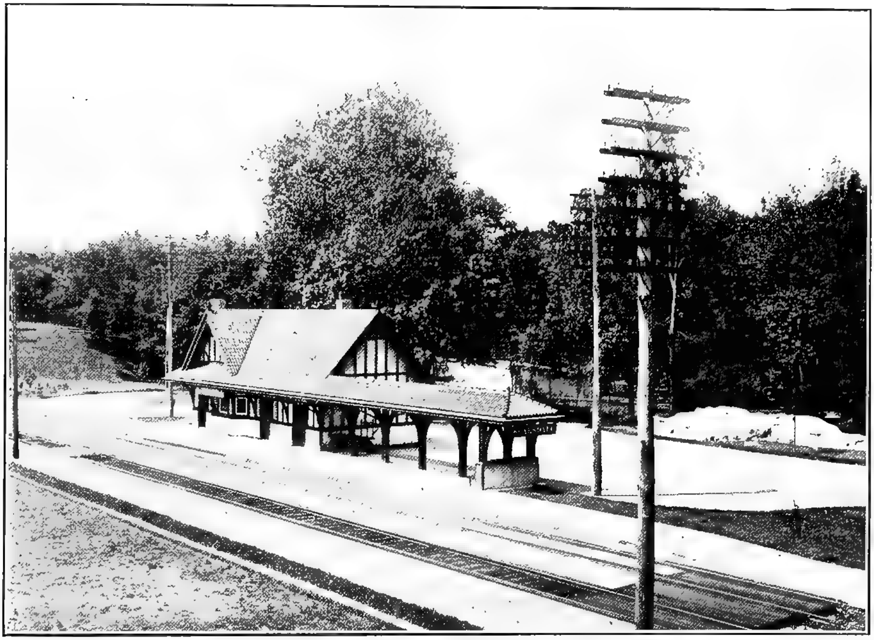

FIG. 65.—SCARSDALE STATION, N. Y. C. & H. R. R. R.

courses and platform columns. Its permanence, fire resisting qualities and adaptability to architectural treatment renders it a most satisfactory building and structural material for both large and small stations. In addition to the Marathon Station, the O'Fallon Station and the Bush Train Shed, a number of other concrete stations are shown among the miscellaneous photographs at the end of the book.

SCARSDALE STATION, N. Y. C. & H. R. R. R. The photograph in Fig. 65 shows a very artistic concrete station at Scarsdale, on the Harlem division of the New York Central and Hudson River Railroad.

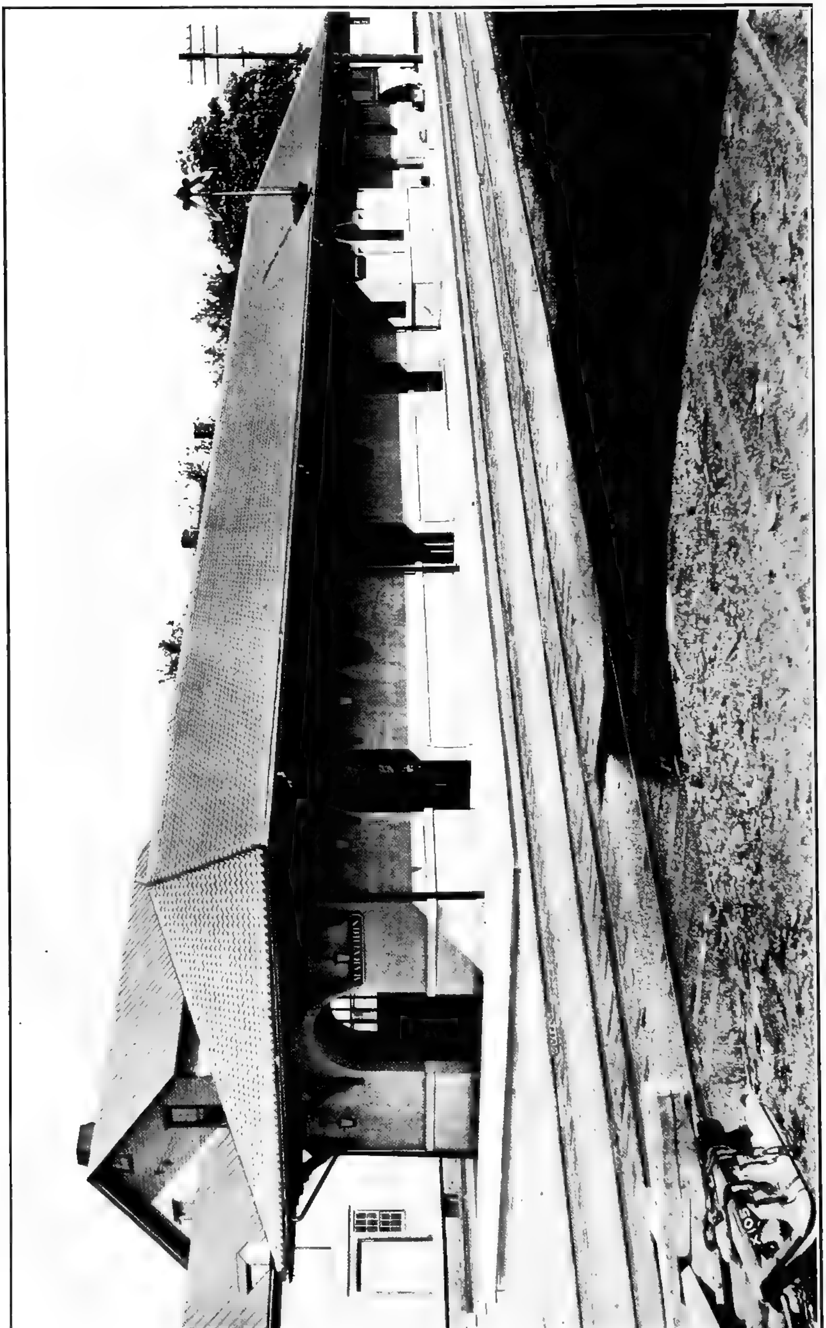

FIG. 66.—MARATHON STATION, D., L. & W. R. R.

MARATHON STATION, D., L. & W. R. R. This structure, a photograph of the track side of which is shown in Fig. 66, is a combination passenger station and freight house of simple, yet artistic design and substantial construction.

With the exception of the roof, which is of Ludowici Celadon tile on wooden rafters, and the trusses and brackets, the building is of concrete construction throughout. The foundations and main walls are of plain concrete, except over square openings where reinforced lintels are formed by placing three ¼-inch square rods near the soffit, while the floors and platforms are of plain concrete laid directly on a cinder base and surfaced with a 1½-inch granolithic finish.

The walls are tool finished up to the water-table, and above that, with the exception of the belt course, are finished by floating the green concrete with water and rubbing with wire brushes immediately after removing the forms.

All the concrete was mixed in the proportions of 1 part Atlas Portland Cement to 2 parts sand and 4 parts broken stone.

The station was designed by Mr. F. J. Nies, architect for the railroad, under the supervision of Mr. Lincoln Bush, Chief Engineer, and was built by A. E. Badgely, general contractor, of Binghamton, N. Y.

O'FALLON STATION, WABASH R. R. This station, a photograph of which is shown in Fig. 67, is typical of a class of small fireproof stations which the Wabash Railroad are erecting to take the place of the ordinary combustible frame building formerly used.

They are built in three sizes, 20 by 40 feet, 20 by 52 feet, and 20 by 62 feet, and consist of plastered walls with floors, platform, foundations and chimney of concrete. These stations are erected at about the cost of the ordinary frame building, and in addition to being fireproof present a better appearance than the former type of structure.

In furring for the outside plastering of the walls, pieces of ½-inch diameter plain round rods 4 inches long are fastened to the studs every 12 inches and against these are wired ½-inch round rods placed longitudinally every 12 inches. To these horizontal rods, sheets of spiral expanded metal lath, No. 26 gauge, 16 inches wide by 96 inches long, are wired, the long dimension being placed vertically. After this is plastered, the inside of the building is furred in a similar manner, except that the horizontal rods are nailed directly to the studding.

The plaster for the first coat consists of a mixture of three cubic feet of well slacked lime mortar to one bag of Atlas Portland Cement. This scratch coat is applied to both sides of the expanded metal attached to the outer side of the studding and to the exposed surface of the expanded metal on

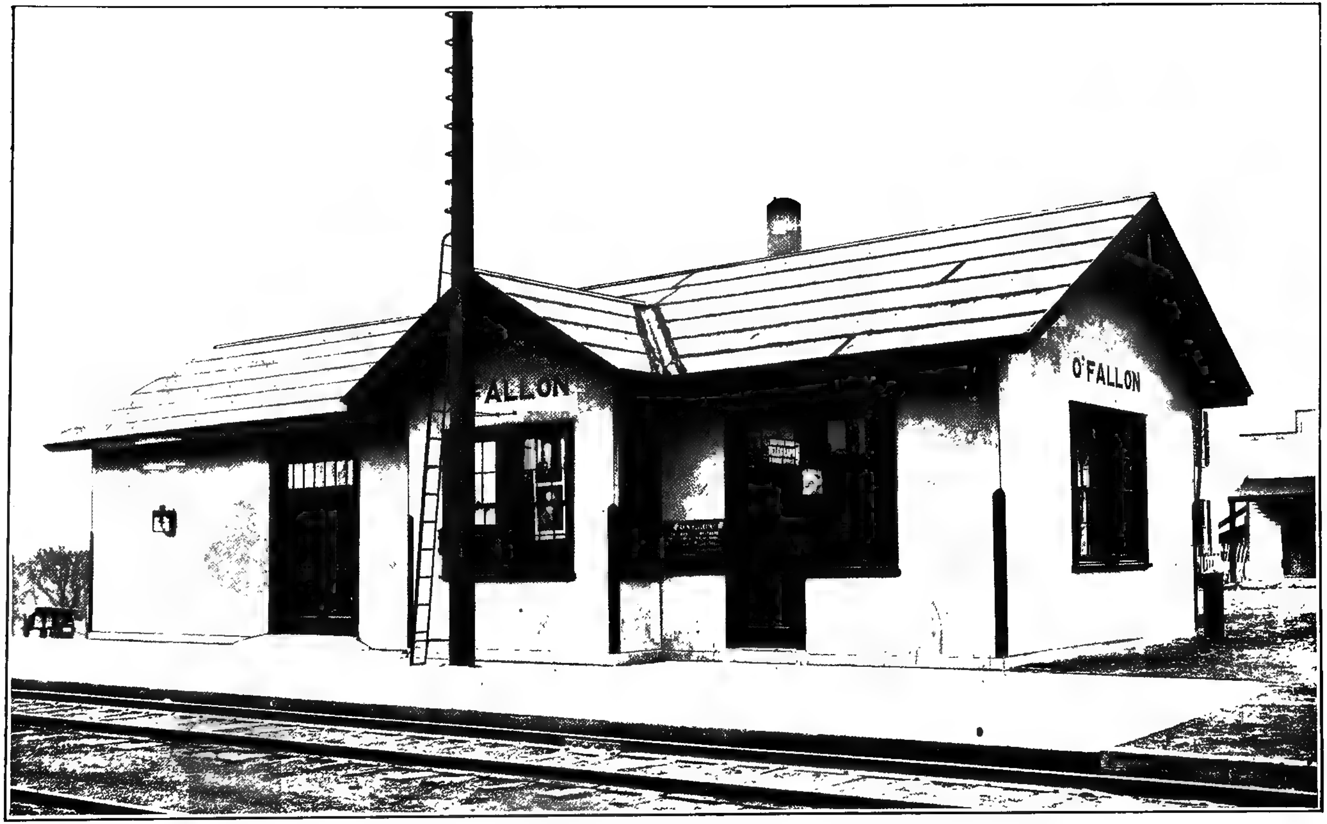

FIG. 67.—O'FALLON STATION, WABASH R. R.

the inside. When this coat has become sufficiently hard both sides of the outer metal lath are plastered until a thickness of $1\frac{1}{2}$ inches is attained, and the inner metal lath is plastered to a thickness of 1 inch, using for the finishing coat cement mortar in proportions one bag of Atlas Portland Cement to 2 cubic feet of sharp, clean sand.

After the walls are dried the outside surface is painted with two coats of waterproofing compound put on thick enough to fill in and hide all joints and hair cracks.

In the new depots of this type the walls up to the window sills are built of solid concrete, which greatly improves the strength and general appearance of the structure.

These stations are designed by and built under the supervision of the Engineering Department of the Wabash Railroad, Mr. A. O. Cunningham, Chief Engineer.

FIG. 68.—HOBOKEN TERMINAL TRAIN SHED, D., L. & W. R. R.

TRAIN SHEDS.

HOBOKEN TERMINAL TRAIN SHED, D., L. & W. R. R. The train shed for the new Lackawanna passenger terminal at Hoboken, N. J., a part section of which is shown in Fig. 69, is an entirely new departure from the

hitherto considered standard type of structure for this purpose. Instead of comprising a series of high arches, which in the common type of train shed are continually enveloped in a haze of smoke and gases from the locomotives, it consists essentially of a system of low arched short span longitudinal sections, just high enough to clear the largest locomotive in use on the line, with smoke ducts of reinforced concrete through which the locomotive gases are dis-

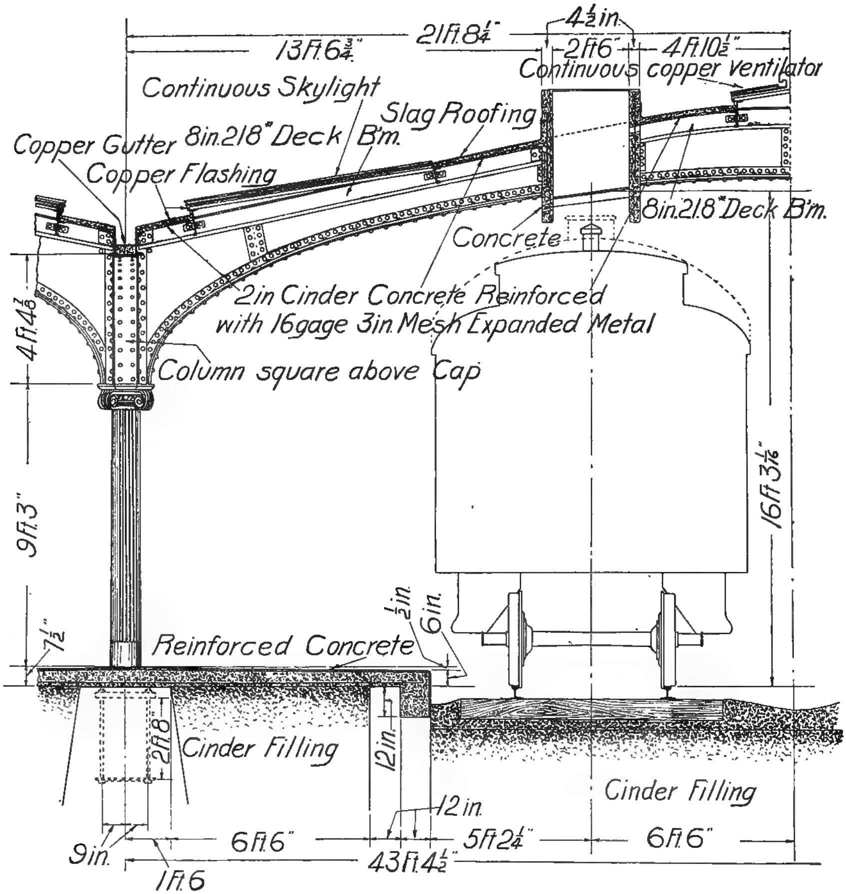

FIG. 69.—PART SECTION, HOBOKEN TRAIN SHED, D., L. & W. R. R.

charged directly into the open air. As will be seen from the section in Fig. 69 and from the photograph in Fig. 68, each of these sections cover two tracks and the sides of the smoke ducts are built high enough to prevent driving rain or snow from reaching the platforms. In addition to the smoke ducts the roof, platforms and fence footings are of concrete construction.

This shed was designed and patented by Mr. Lincoln Bush, Chief Engineer of the Delaware, Lackawanna and Western Railroad, and erected under his supervision by the company forces in 1907.

The same type of train shed has also been used by the Lackawanna Railroad at the new Scranton station and by the Chicago and Northwestern Railway Co. at its new terminal in Chicago.

FIG. 70. -COHOES STATION AND PLATFORM, N. Y. C. & H. R. R. R.

PLATFORMS.

While plain concrete has been used for many years in the construction of low platforms at main stations the adoption of high platforms on rapid transit and suburban lines during the past few years has opened up a new field for reinforced concrete. A typical ground platform is shown in Fig. 71, while two types of high platforms of reinforced concrete are illustrated and described on pages 106 to 111.

STANDARD CONCRETE GROUND PLATFORMS AT STATIONS, N. Y. C. & H. R. R. R. These platforms, a typical one of which is shown in cross section and plan in Fig. 71, and by the photograph in Fig. 70 are usually constructed 200 feet long and 12 feet wide and are divided into blocks of not more than 40 square feet area. The platform illustrated in Fig. 71 is for only

one passenger track, but if more than one track is used another 12-foot platform is provided opposite and outside of the additional passenger track or tracks.

The concrete is mixed in the proportions of 1 part Portland cement to 3 parts sand to 6 parts broken stone and the granolithic finish in the proportions of 1 part cement to 1½ parts sand.*

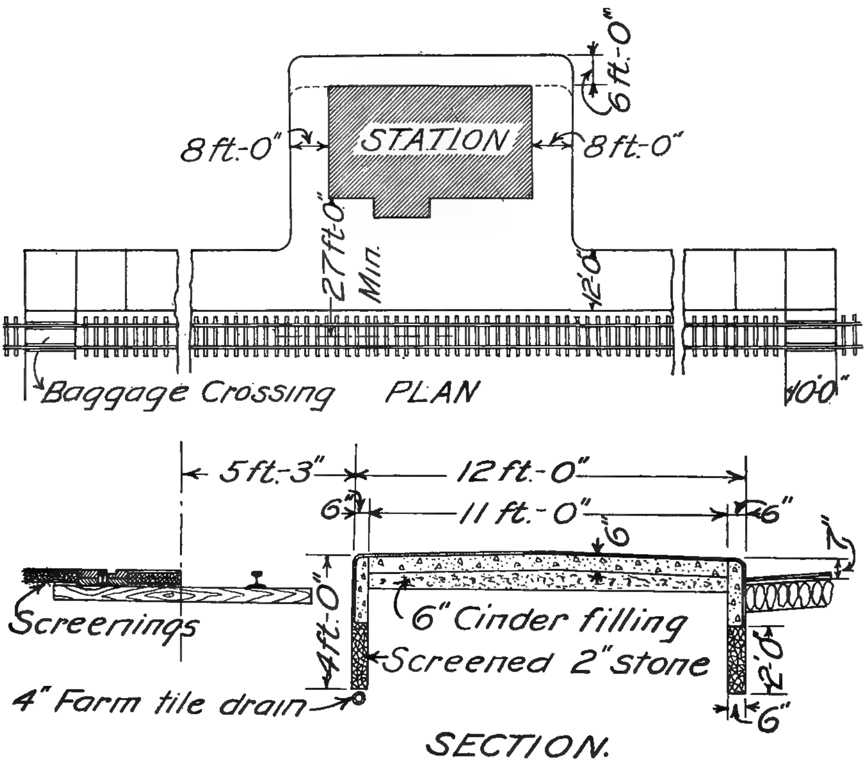

FIG. 71.—STANDARD GROUND PLATFORM, N. Y. C. & H. R. R. R.

STATION PLATFORMS, BROOKLYN RAPID TRANSIT CO. The platforms on either side of the tracks are about 240 feet long and 8 feet wide and are constructed of a reinforced concrete slab carried by girders of the same material which are in turn supported by concrete piers placed about every 20 feet. The photograph in Fig. 72 shows the track side of one of the platforms while the drawings in Fig. 73 show the essential features of design and construction.

*The details of sidewalk and platform construction are discussed in "Concrete in Highway Construction," published by the Atlas Portland Cement Company.

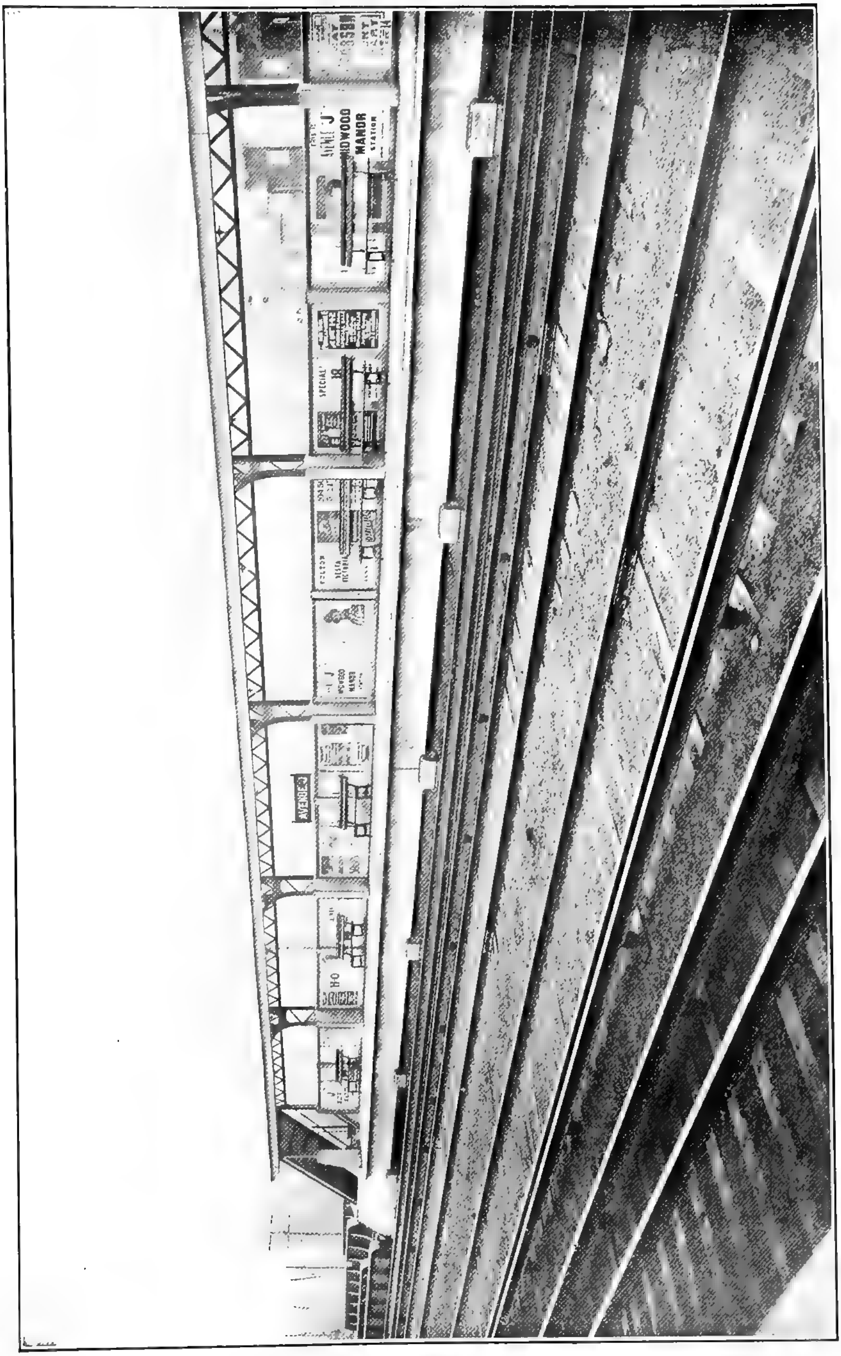

FIG. 72 – AVENUE J STATION PLATFORM, B. R. T. CO.

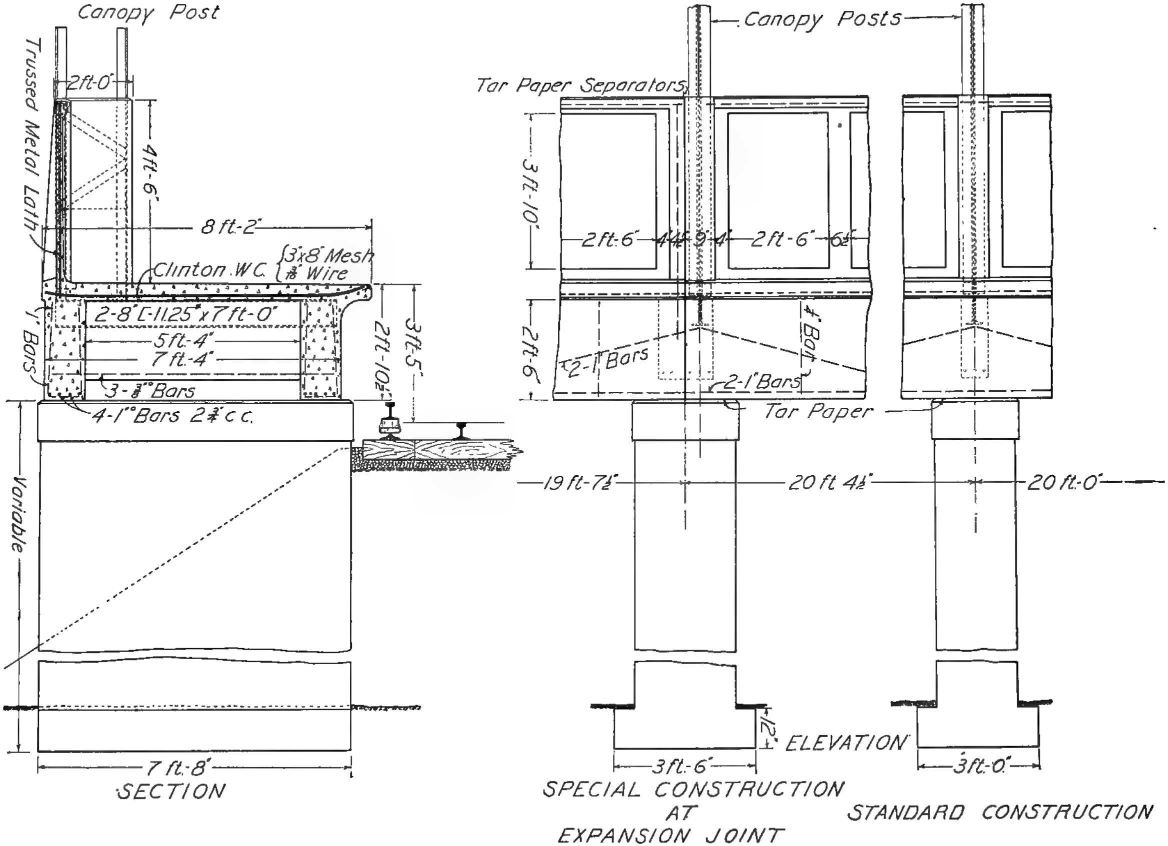

FIG. 73.—DETAILS OF CONSTRUCTION, STATION PLATFORMS, B. R. T. CO.

Expansion joints are provided every 60 feet by separating the construction entirely with tarred paper.

The outside edges of the platform are equipped with patent bulb nosing.

The fences running the length of the platform and forming the guard railings on the outside and ends of the platforms are constructed of cement plaster on metal lath and are described in detail in Chapter XVI.

For the concrete work a mixture of 1 part Atlas Portland Cement to 2 parts sand to 4 parts ¾-inch broken stone was used throughout. The 1-inch granolithic surface of the platforms was mixed in the proportions of 1 part Atlas cement to 1 part sand and 1 part pebble grit and was applied simultaneously with the last course of concrete.

In designing the platforms, a live load of 150 pounds per square foot was assumed and the concrete was figured at 500 pounds per square inch extreme fiber stress while the steel was allowed 16,000 pounds per square inch in tension.

The platforms were designed by the Engineering Department of the Brooklyn Rapid Transit System, Mr. W. S. Menden, Chief Engineer, and were constructed under his supervision by Mr. Thomas G. Carlin of Brooklyn, in 1907.

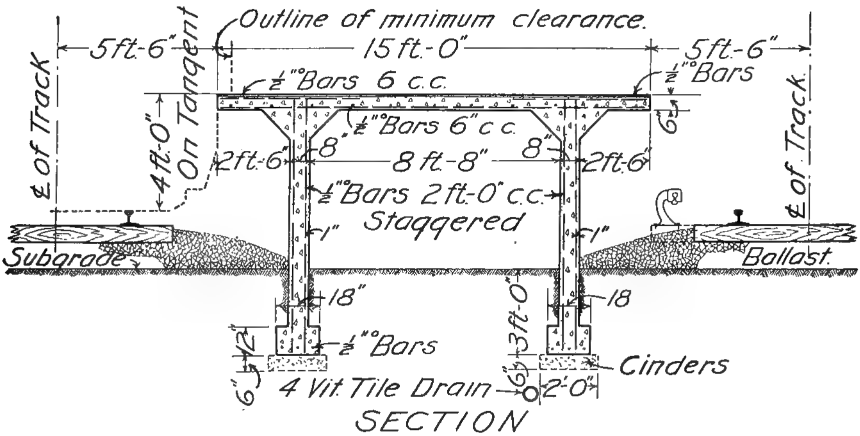

FIG. 74.—CROSS SECTION OF STANDARD ISLAND PLATFORM. N. Y. C. & H. R. R. R.

ELECTRIC ZONE STANDARD PLATFORMS, N. Y. C. & H. R. R. R.

One of the most important features of the Electric Zone improvement work of the New York Central and Hudson River Railroad is the adoption of high platforms on the suburban side of all local stations within the Zone. This not only enables greater ease in the interchange to and from trains, but greatly increases the rapidity of the service.

As will be seen from the cross-sections in Figs. 74 and 75, which show the details of construction of an island and outside platform, the type adopted comprises two longitudinal reinforced 8-inch walls with a 6-inch reinforced deck or floor plate spanning the walls and overhanging 2 feet 6 inches on either side. The width varies from 12 to 15 feet, while the height is determined by the elevation of the rails according to the degree of curve, which is four feet above the rails on tangents and curves up to three degrees and thirty minutes.

In plan the arrangement of the platform varies greatly according to the location. The suburban stations have high platforms about 350 feet long, on

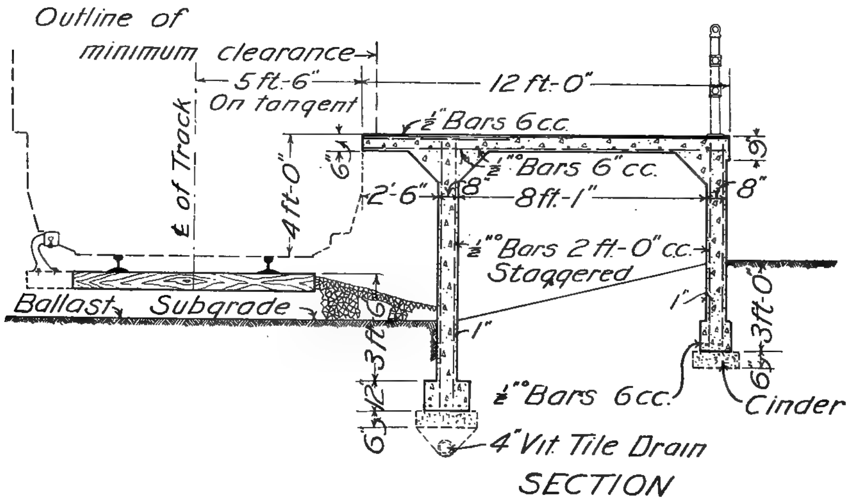

FIG. 75.—CROSS SECTION OF STANDARD OUTSIDE PLATFORM, N. Y. C. & H. R. R. R.

either side, outside of the group of four tracks, and the combination stations have two high outside platforms and a middle low platform between the express tracks on both sides, with a high platform at one end for a distance of 350 feet and a low one of the same length adjoining it.

All stations are provided with overhead bridges or subways connecting with the various platforms.

The concrete is of 1:3:6 proportions, with exposed surfaces faced with ½-inch cement finish mixed in the proportions of 1 cement to 1½ sand. All exposed edges are rounded to a 1-inch radius.

The platforms are divided into blocks of not more than 40 square feet area and expansion joints are to be provided every 25 to 40 feet.

These platforms are designed by the engineering force of the N. Y. C. & H. R. R. R. under the supervision of Mr. George A. Harwood, Chief Engineer of Electric Zone Improvements.

CHAPTER VIII.

COAL AND SAND STATIONS AND ASH HANDLING PLANTS.

Reinforced concrete is peculiarly adapted to the construction of structures which are to be used for the storage of coal on account of its undoubtable fire-resisting qualities, permanence and strength.

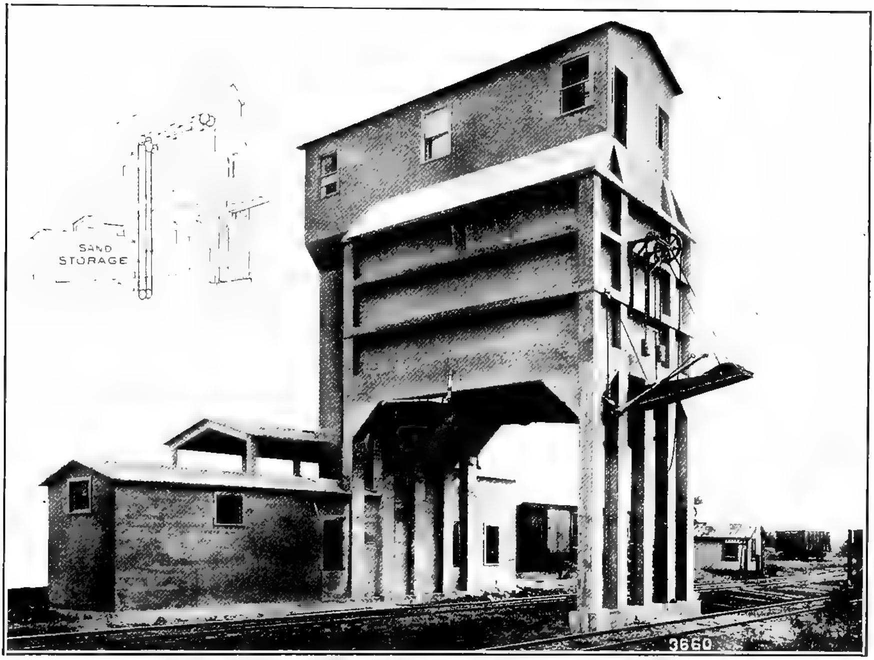

FIG. 76.—COAL AND SAND STATION, N. & W. RY.

Through the use of inferior bins such as have been constructed of timber or steel, the railroads of this country have suffered much inconvenience and heavy expense. The spontaneous combustion to which coal is subject when stored in great quantities not only results in the loss of the coal itself and the damaging of much valuable machinery, but also in the destruction of the bin, if it is constructed of either wood or steel.

This condition has led to entirely reinforced concrete structures, even though the initial cost is higher than for wood or steel. The coal and sand stations which have thus far been constructed of reinforced concrete have given entire satisfaction.

CONCORD COAL AND SAND STATION, N. & W. RY. This combination coaling and sand station, shown by the photograph in Fig. 76, was built and entirely equipped for the Norfolk and Western Railway by the Link Belt Co. of Philadelphia during the summer of 1907. The reinforced concrete

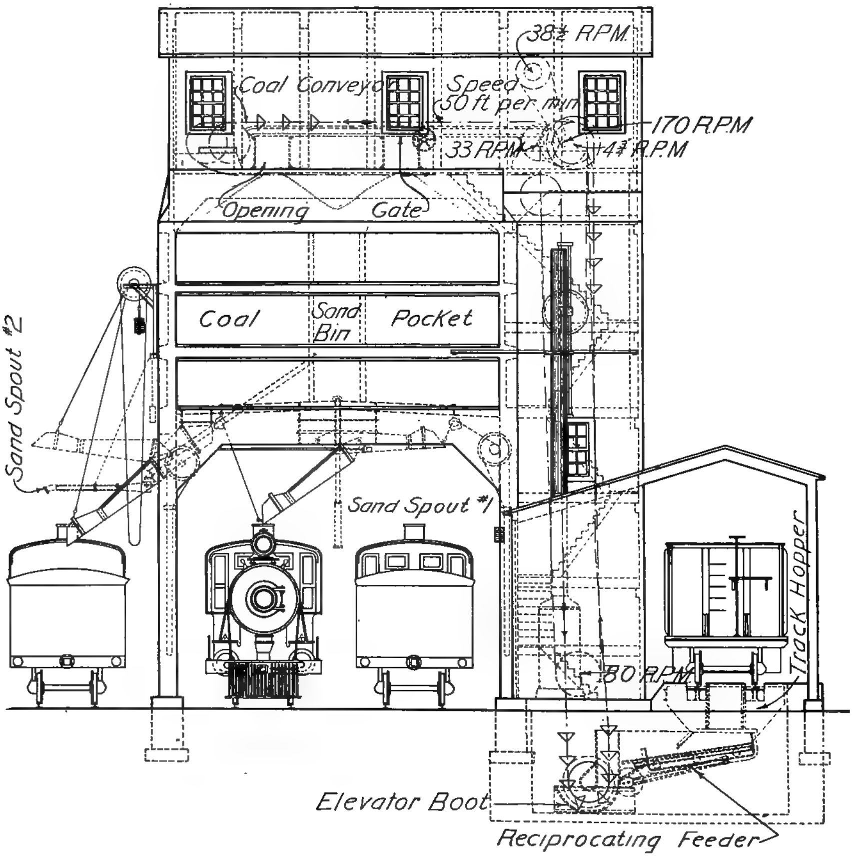

FIG. 77.—CROSS-SECTION SHOWING MECHANICAL EQUIPMENT OF CONCORD COAL AND SAND STATION.

details were designed and worked out by Mr. Walter Loring Webb, Consulting Engineer, of Philadelphia, and the concrete work was sublet to McLaughlin Brothers, of Baltimore, Md.

In general the station consists of an elevated coal pocket having a capacity of 260 tons of coal, and a wet sand storage house on the ground with an elevated dry sand bin. From a study of the drawing in Fig. 77, showing the mechanical equipment of the plant, it will be seen that the coal is brought to

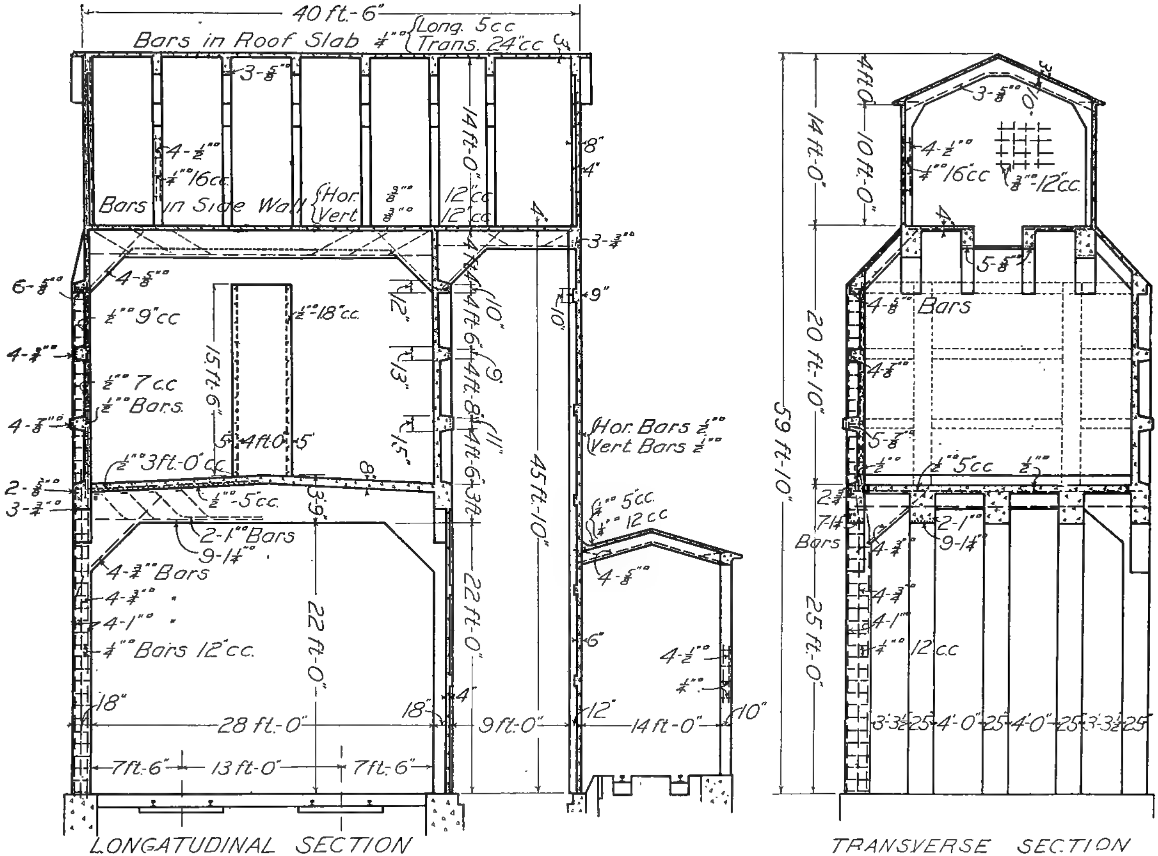

FIG. 78.– LONGITUDINAL AND TRANSVERSE SECTIONS, CONCORD COAL AND SAND STATION.

the pocket on a side track, and dumped through a 10 by 12 foot track hopper into a reciprocating feeder which delivers it into a steel bucket elevator discharging into a conveyor trough above for distribution into the pocket. The photograph in Fig. 79 shows the conveyors and the conveyor trough over the pocket. The coal is fed to the engine tenders through hinged gates and over counterweighted coaling chutes, two directly under the pocket and two over the track in front of the pocket. The wet sand passes into a dryer emptying into a sand pit underneath, where it is scooped up and carried by a sand elevator which dumps it from above into the dry sand bin. From this bin it is fed to the engines through two telescopic sand spouts.

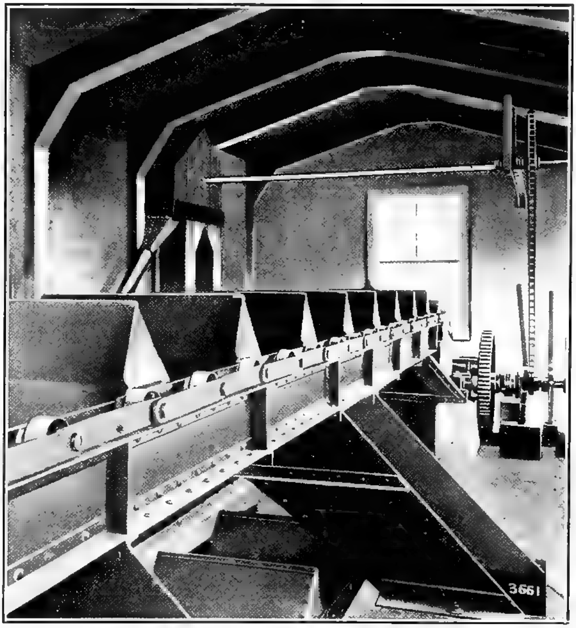

FIG. 79.—CONVEYORS OVER COAL POCKET, CONCORD COALING AND SAND STATION.

In designing the structural features of the station, the unit compression in the concrete was taken as 500 pounds per square inch, and the tension in the steel as 16,000 pounds per square inch. The side walls were designed on the basis of the computed lateral pressure exerted by bituminous coal weighing 47 pounds per cubic foot. This gave a maximum lateral pressure of 248 pounds at the bottom of the pocket, and a vertical pressure on the bottom slab of nearly 1,000 pounds per square foot. The essential features of design and construction are shown very clearly by the longitudinal and transverse sections in Fig. 78.

In the construction of the building, concrete mixed in the proportion of 1 part Atlas Portland Cement to 2 parts sand to 4 parts broken stone, was used throughout and was mixed in a cube mixer equipped with hoisting engine and elevator and delivered over the work in batch carriers. The cost of the concrete work was $8,600.

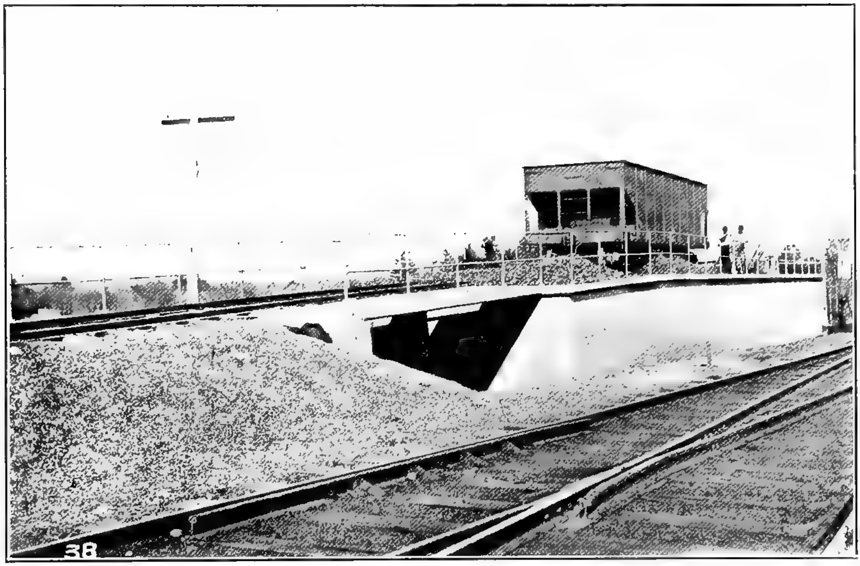

FIG. 80.—MURRAY HILL RETAIL COAL POCKET, D., L. & W. R. R.

ASH HANDLING PLANTS.

Inasmuch as wood burns and steel corrodes, it has long been a problem as to how to build ash handling plants capable of withstanding the destructive effect of ashes quenched with water. The advent of reinforced concrete into the field of railroad construction has successfully solved this problem. At the present time most of the plants being built throughout the country consist of a steel framework which support bins constructed of reinforced concrete. The accompanying photograph in Fig. 82 is a good example of such a plant designed and erected in 1905 by the Link Belt Company for the Norfolk & Western Railway at Bluefield, W. Va.

The ash bin has a storage capacity of 30 tons. Ashes are dumped from the engine into 1-ton tubes which rest on trucks in the dump pit below, with their tops flush with the rails, and are raised, dumped into the bin and returned automatically by an electric hoist. In the photograph one of the skips is seen in action, while on the drawing in Fig. 81 is shown a cross section of the dump

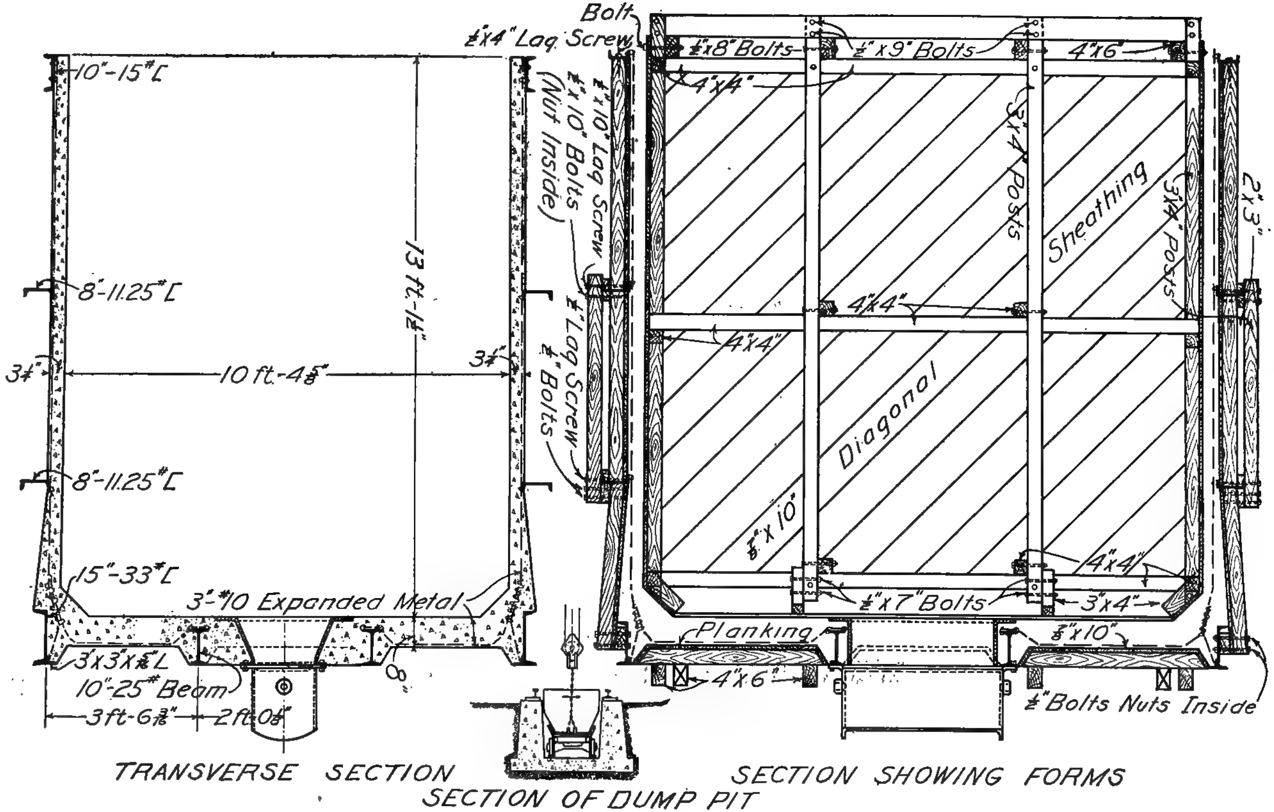

FIG. 81.—SECTION OF ASH BIN SHOWING FORMS, BLUEFIELD ASH HANDLING PLANT.

pit. The ashes are emptied from the bin through a discharge gate into cars on a track directly beneath.

The details of construction of the concrete work of the bin are shown in Fig. 81 together with the forms and the manner in which they were supported by the steel framework of the building. The cost of the concrete work including the forms was about $700.

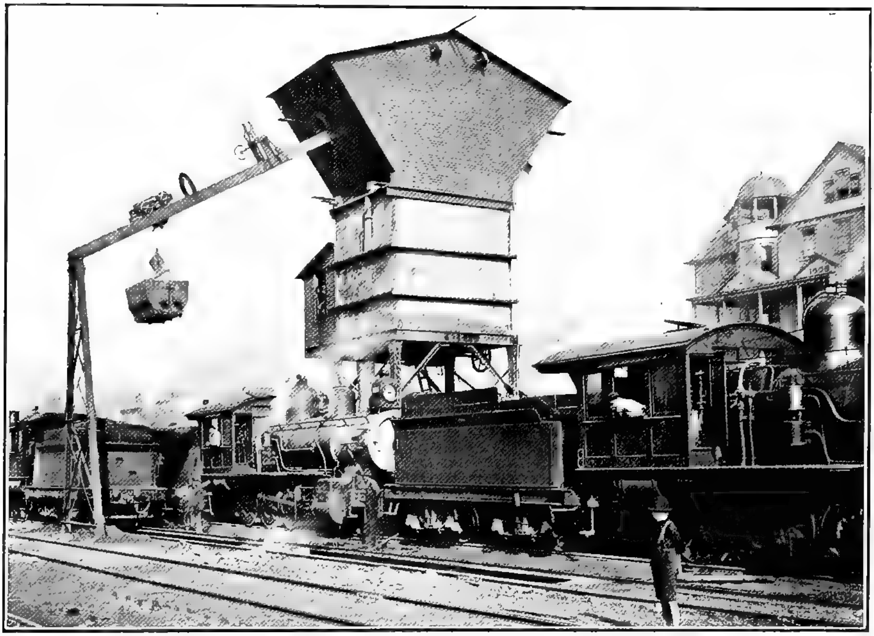

FIG. 82.—ASH HANDLING PLANT, BLUEFIELD, W. VA., N. & W. RY.

HOBOKEN COAL TRESTLE, D., L. & W. R. R. As shown by the photograph in Fig. 83, this trestle forms an approach by which loaded coal cars may be taken to the level of the second floor of the power house where the coal is dumped to the space in front of the boilers. It will be seen that the trestle proper, which is 226 feet 3 inches long, comprising 18 bents on piers spaced 12 feet on centers, has for an inner abutment the wall of the power house and for the outer abutment the end of an approach 112 feet 4 inches long.

From out to out the trestle is 16 feet wide, about one-half this width being taken up by a walk each side of the track.

The footings, which rest on piles, are 4 feet 9 inches wide and 3 feet thick.

Each pier is 19 feet wide and 18 inches thick at the top with a batter of 1 inch per foot in cross section of the trestle and ½ inch per foot in longitudinal

section, and is reinforced vertically with ¾-inch square bars placed in two rows 3 inches from the outside of the pier, 5 inches on centers underneath the stringers, and 9 inches on centers between the stringers. In addition to these vertical bars, similar ones are placed horizontally 18 inches apart.

The beams or stringers resting on these piers are 18 inches by 27 inches, and are reinforced with three 1¼-inch square bars, two being bent up at the quarter points to take care of the diagonal tension. Over each pier the top of the stringer is also reinforced with four 1½-inch square bars 8 feet 4 inches long. Every two feet, ¾-inch bolts 12 inches long are embedded 9¼ inches in the top of the stringer to which are secured clamps for holding the rails in place.

FIG. 83.—COAL TRESTLE, HOBOKEN, N. J., D., L. & W. R. R.

As will be seen from the photograph in Fig. 84, the sidewalks are carried by an inverted rail at each bent which extends the width of the trestle. To these rails clips are attached every 6 inches with openings in each leg through which the rods forming the reinforcement of the sidewalk are passed.

A mixture of 1:2:4 was used throughout.

The trestle was designed and constructed by the Engineering Department of the Delaware, Lackawanna and Western Railroad in 1907 under the supervision of Mr. Lincoln Bush, Chief Engineer, and Mr. George T. Hand, Assistant Engineer, with Mr. E. I. Cantine as Division Engineer.

FIG. 84.—HOBOKEN COAL TRESTLE UNDER CONSTRUCTION, D., L. & W. R. R.

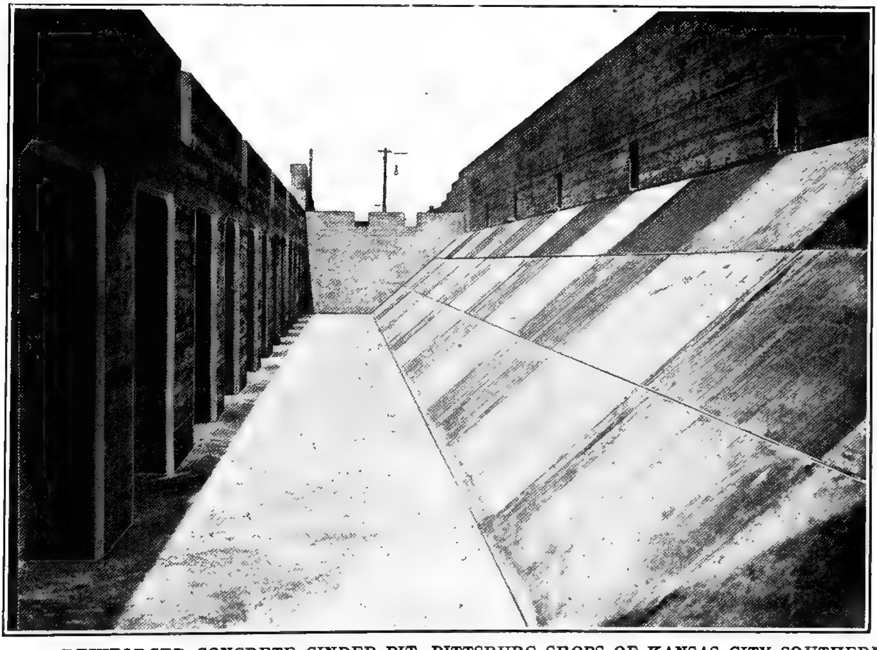

FIG. 85.—REINFORCED CONCRETE CINDER PIT, PITTSBURG SHOPS OF KANSAS CITY SOUTHERN RY.
Built by Arnold & Co., of Chicago.

FIG. 86.—TURNTABLE PIT, ATCHISON, TOPEKA AND SANTA FE RY. (See page 127.)

CHAPTER IX.

ROUNDHOUSES AND TURNTABLE PITS.

ROUNDHOUSES.

The adaptability of concrete to roundhouse construction is clearly demonstrated in the report* submitted on that subject by the Committee on Buildings of the American Railway Engineering and Maintenance of Way Association before the annual convention of that society held in Chicago, March, 1908.

For the purpose of discussion, the roundhouse was considered divided into Foundations and Pits, Roof, Supporting Columns and Outer Walls; and excerpts from the report are given below in the order named.

FOUNDATIONS AND PITS. "While in some cases local conditions may favor the use of stone or brick for foundations and pits, it may be stated, as a general proposition, that good practice in roundhouse construction now requires the use of concrete for these parts of the structure. When a solid foundation cannot be obtained within a few feet below the floor level of the building a considerable saving may be effected by the use of reinforcement."

ROOF. "In economy of first cost, durability and fire-resisting qualities, there is no other fireproof roof construction which is equal to reinforced concrete. Steel except as a reinforcement for concrete is not a satisfactory material for engine house roof construction."

SUPPORTING COLUMNS. "If the roof is of reinforced concrete, it should be supported by columns of the same material in the outer and end walls, as well as in the interior of the building. These columns should be concreted with the roof, the concrete being run into the forms from above. The columns on the inner circle to which the doors are attached should be of some other material than concrete, preferably steel or cast iron."

OUTER WALLS. "For a structure roofed with reinforced concrete, the curtain walls may be of brick, plain concrete, reinforced concrete or plaster. Concrete will, if properly made, give good service and local costs of materials and labor would ordinarily determine which of the first three styles of curtain walls named above should be built. The plaster curtain wall may be used where it is desirable or necessary to reduce the first cost to a minimum.

"To build such a wall Portland cement is mixed with enough lime so that it can be worked with a trowel and is plastered on expanded metal. The lat-

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*Proceedings of the Ninth Annual Convention, Vol. 9, p. 166.

COSTS OF REINFORCED CONCRETE ROUNDHOUSES COMPARED WITH OTHER TYPES.

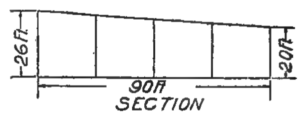
Type		First Cost							Average Annual Charges for First Ten Years			
Roof	Walls	Roof Covering	Front Post	Roof, Beams and Posts	Walls	Mill Work, Includ'g Painting	Contin-gencies 5%	Total	Interest and De-preciation 10.4%	Insur-ance	Main-tenance	Total
Reinforced Concrete, 25-50 stalls.	Concrete...	18 squares, @ $4.00. $72	Cast iron.. $20	43.3 cu. yds. rein. conc. @ $13. $563	5.5 cu. yds. concrete @ $10. $55	$250	$48	$1,008	$105	....	$25	$130
Reinforced Concrete, 25-50 Stalls.	Brick......	18 squares @ $4.00. $72	Cast iron... $20	42 cu. yds. rein. conc. @ $13. $546	5,000 brick @ $16. $80	$250	$48	$1,016	$106	....	$25	$131
Reinforced Concrete, 25-50 Stalls.	Plaster.....	18 squares @ $4.00. $72	Cast iron... $20	43.3 cu. yds. rein. conc. @ $13. $563	16 sq. yds. plaster @ $1.75. $28	$250	$47	$980	$102	....	$27	$129
Reinforced Concrete, 15-25 Stalls.	Plaster.....	18 squares @ $4.00. $72	Cast iron... $20	43.3 cu. yds. rein. conc. @ $14. $606	16 sq. yds. plaster @ $1.75. $28	$250	$49	$1,025	$107	....	$27	$134
Wood................	Brick......	18 squares @ $4.50. $81	Wood..... $15	9,000 feet lumber @ $40. $360	5,300 brick @ $16, Steel Lint'l $125	$250	$42	$873	$81	1% on total cost. $22	$25	$138
Wood................	Plaster.....	18 squares @ $4.50. $81	Wood..... $15	9,500 feet lumber @ $40. $380	40 sq. yds. plaster @ $1.25, 200 ft. lumber @ $40. $58	$250	$39	$823	$86	1% on total cost. $21	$30	$137
Wood................	4 ft. conc. to window sills, wood above.	18 squares @ $4.50. $81	Wood..... $15	9,500 feet lumber @ $40. $380	4 cu. yds. concrete @ $7, 300 ft. lumber @ $40. $40	$250	$38	$804	$83	1.2% on total cost. $26	$32	$141

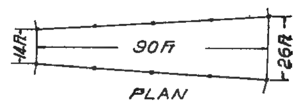
Costs shown are in dollars per stall and include structures only above foundations without jacks, pits, ventilators, piping, etc. Windows to occupy all available space above doors on inner circle and between pilasters in outer circle, and dimensions to be as shown on accompanying sketch.

Insurance is figured on the total cost of the house.

The estimates are based on the following prices of material.

Brick....................	$9.00 per M.	Cement....................	$1.50 per bbl..
Lumber form..............	23.00 "	Sand......................	0.75 per cu. yd.
Lumber, permanent........	28.00 "	Stone.....................	0.60 "
Reinforcing Steel........	2¼c. per lb.		





COMPARISON OF COST OF DIFFERENT TYPES OF ROUNDHOUSES.

ter is stiffened with rods and channel irons, which are used to support the window frames. A wall of this character can be built more quickly than a concrete wall, is efficient and should be durable. If damaged by a locomotive or otherwise, it is easily repaired, and alterations can be readily made. Used with concrete columns, it should not crack, and its first cost is but about half that of a brick wall."

COST. "The cost of concrete construction in roundhouses depends largely upon the number of times the forms can be used. It follows, therefore, that where the structure is large and the forms for each unit or stall can be used many times in the same roundhouse, the cost per stall is much less than in a small building. Consequently reinforced concrete construction is more economical in large than in small roundhouses, when compared with brick or frame construction."

The costs of the different types of construction are compared in the table* on page 122.

This table gives in detail a comparative statement of the cost and annual charges per stall of six types of roundhouses, the first three being roofed with reinforced concrete and having outer walls of concrete, brick and plaster, respectively, in the order named. The fourth given is the same type as the third and merely shows the increase in unit cost for the reinforced type when the building is reduced in size.

With these figures as a basis it is evident that the concrete house is in the long run more economical, because of its greater permanency and the lesser chance of damage to it and the equipment it contains, by fire and other causes.

In addition to the roundhouse described below a number of different types of concrete roundhouses are illustrated by the photographs in the back of the book.

WATERBURY ROUNDHOUSE, N. Y., N. H. & H. R. R. While this roundhouse as designed includes 22 stalls, the part constructed at the present time consists of 10 stalls, each comprising about 8 degrees of the circle, and is connected at one end to a machine shop.

As will be seen from the radial section in Fig. 89 the house consists of four circumferential rows of hooped concrete columns carrying beams and roof slabs of reinforced concrete.

The entrance, as shown by the stall elevation in Fig. 87, is closed in by large round slat rolling doors between the columns, while the outer circle is encompassed by a brick wall with large glass windows with concrete sills directly in line with the tracks.

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*Proceedings American Railway Engineering and Maintenance of Way Association, Vol. 9, p. 182.

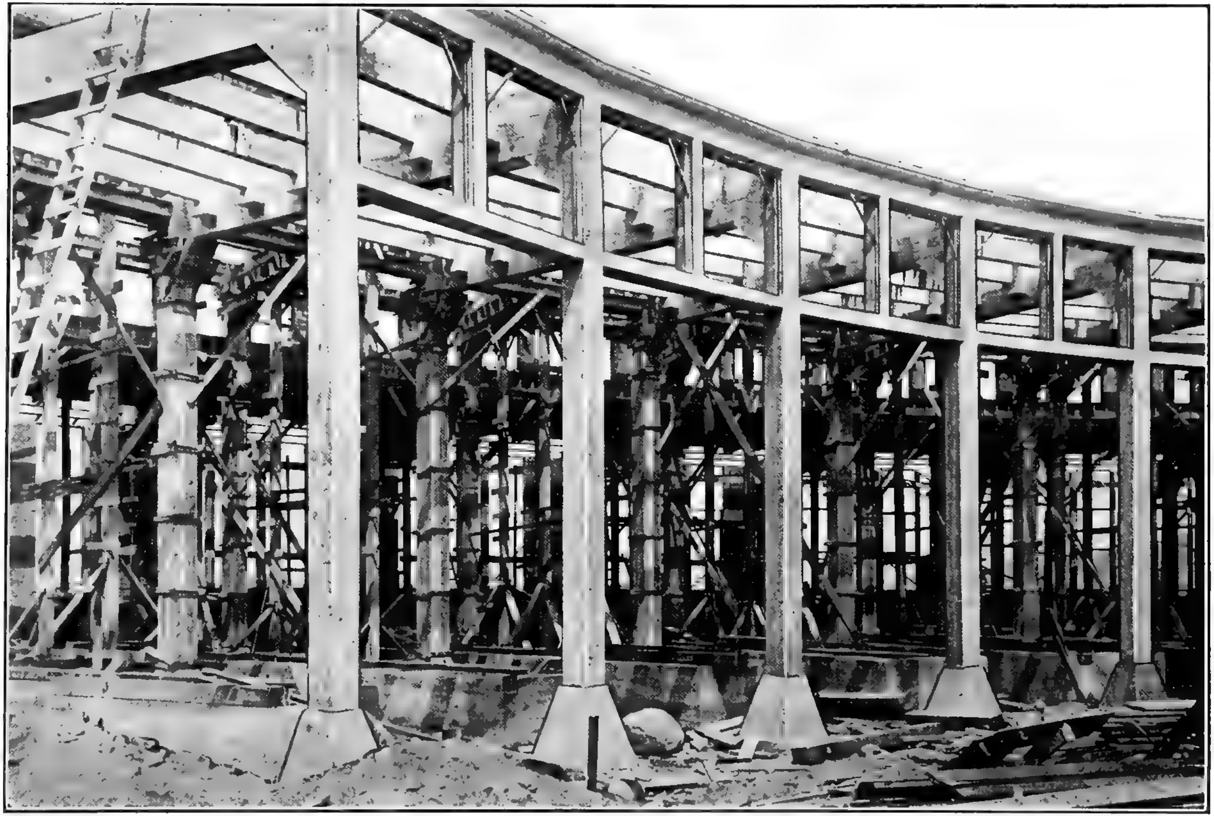


FIG. 87.—WATERBURY ROUNDHOUSE UNDER CONSTRUCTION.

Each stall is equipped with an asbestos lumber smoke-jack and each pit is provided with steam pipes for removing ice and snow from the locomotives. Fig. 88, which is a cross section of a stall pit, shows the arrangement of these pipes.

Permanent compressed air jacks are installed in drop pit under the tracks of two of the longitudinal pits to remove trucks which can then be slid into a transverse pit and thence into the machine shop.

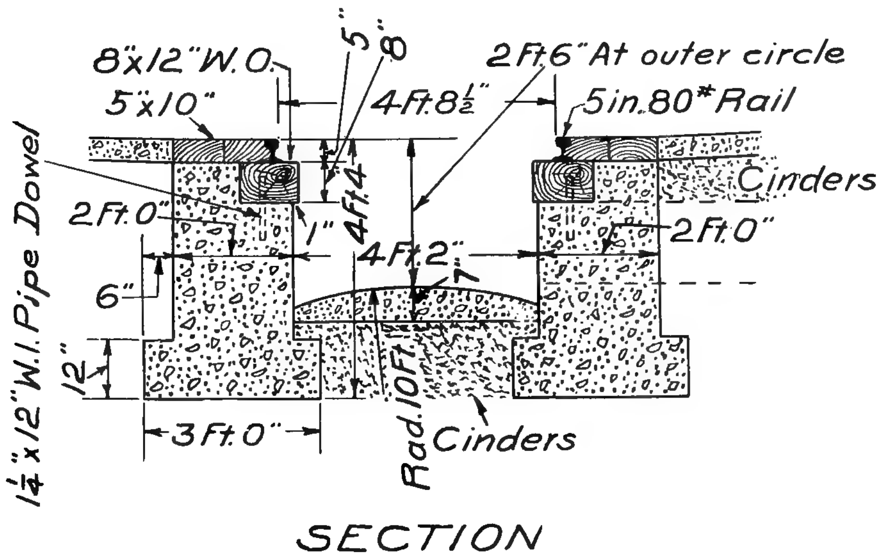


FIG. 88.—CROSS SECTION STALL PIT, WATERBURY ROUNDHOUSE.

The drawings in Fig. 89 show the essential details of design and construction of the columns and roof construction.

The columns are of square section 14 by 14 inches and are reinforced with six ⅝-inch plain square bars hooped with ⅝-inch round hooping ½-inch pitch.

The method employed in constructing the roof presents a rather unique and interesting feature. While the main girders were cast in place in the usual manner the intermediate beams and roof slabs were moulded on the ground, cured and hoisted to their required position and grouted in place. The intermediate beams, set in reinforced bracketed pockets on the main girder to which they are rigidly connected, were locked by extending the reinforcement from both beam and packet and filling the joints with wet concrete. The photograph in Fig. 87 of the roundhouse during erection, shows this form of construction very clearly.

As will be seen from Fig. 89 the slabs which are made in widths of about four feet rest directly on top of the intermediate beams and main girders.

These slabs are 3 inches thick and are reinforced with woven wire mesh fabric.

After the slabs were set, the roof was covered with pitch and slag.

A mixture of 1:2:4 concrete was used throughout in the construction of the roundhouse.

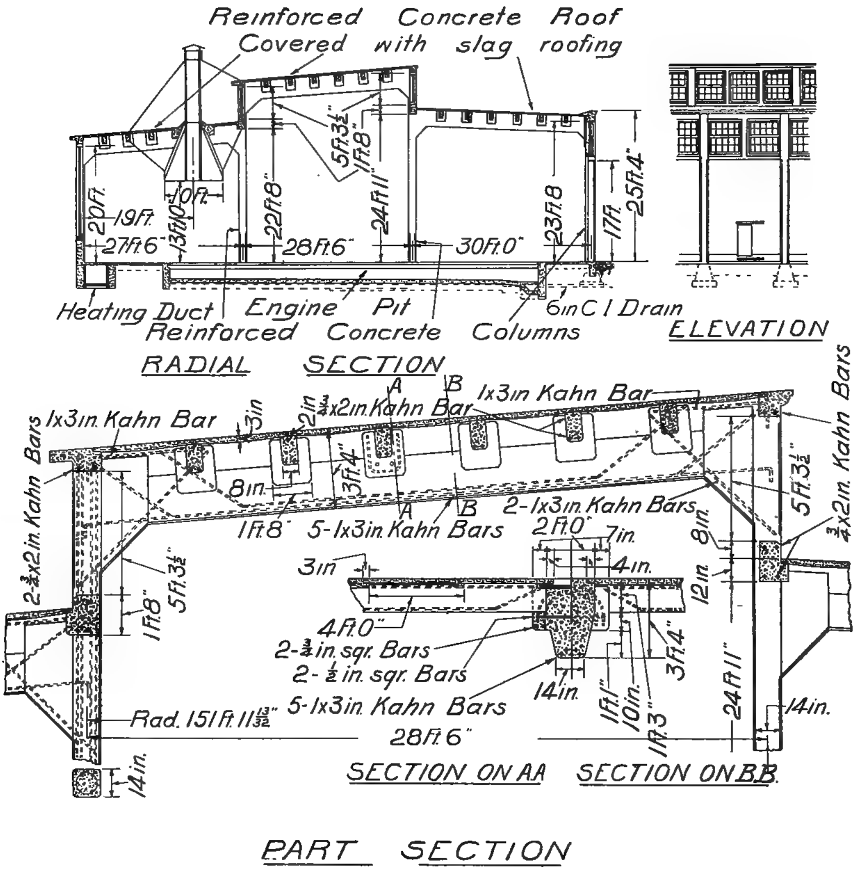


FIG. 89.—RADIAL SECTION WITH DETAILS OF ROOF CONSTRUCTION, WATERBURY ROUNDHOUSE.

The roundhouse was designed by the engineering department of the New York, New Haven and Hartford Railroad, Mr. Edwin Gagel, Chief Engineer, under the direction of Mr. E. H. McHenry, Vice-President, and was built in 1909 by the O'Brien Construction Company of Waterbury.

HURON ROUNDHOUSE, C. & N. W. RY. The photograph in Fig. 90 shows the 40-stall engine house of the Chicago and Northwestern Railway at Huron, S. D., under construction. This is a combination brick and concrete

structure with all of the foundations, pits and underground work of concrete construction. It was built for the Chicago and Northwestern Railway by the Charles W. Gindele Co. of Chicago in 1907.

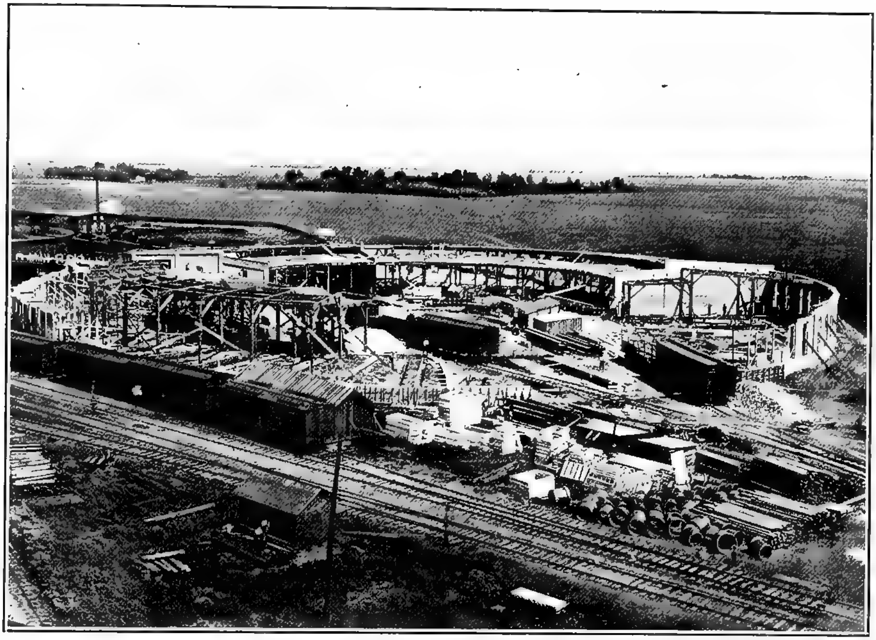


FIG. 90.—HURON ROUNDHOUSE DURING CONSTRUCTION.

TURNTABLE PITS.

In connection with roundhouse construction the subject of turntable pits is of special interest. The facility and cheapness with which concrete pits can be built is so generally recognized that practically all turntable pits constructed to-day are built of concrete.

The photograph in Fig. 86, page 120, is of a standard turntable pit on the Santa Fe System, while the drawings in Fig. 91 show the standard pit for a 30-foot turntable on the N. Y. C. & H. R. R. R.

STANDARD PIT, N. Y. C. & H. R. R. R. Fig. 91 shows the essential details of design and construction of this pit, together with a drawing of the turntable itself.

As will be seen from the drawings in Fig. 91, the turntable is supported by a center pier surmounted by a complete templet 5 feet by 5 feet by 1 foot 6 inches. The concrete for the pier itself is mixed in the proportion of 1 part

Portland cement to 3 parts sand to 6 parts broken stone and the templet or cap in the proportions of 1:1:2.

The floor of the pit consists of 4 inches of 1:2:4 concrete laid on 8 inches of well tamped cinders.

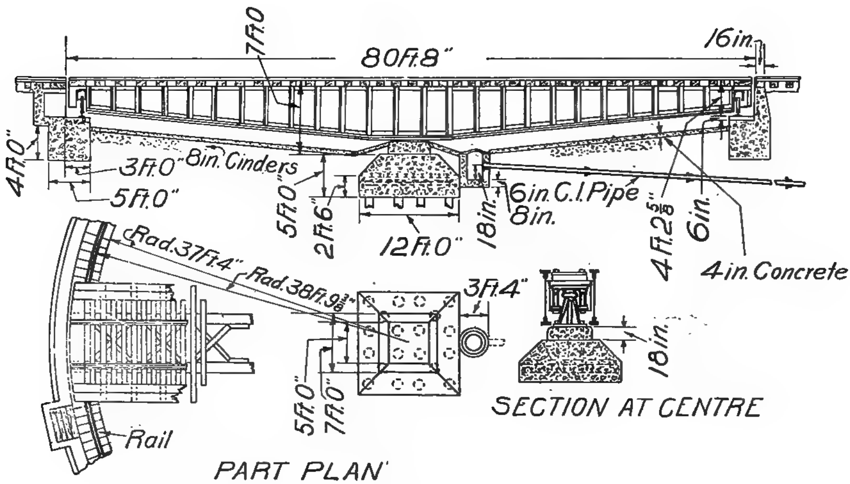


FIG. 91.—STANDARD 80-FT. TURNTABLE PIT, N. Y. C. & H. R. R. R.

The circular run rail is carried on a seat of 1:3:6 concrete resting on a foundation 5 feet wide and 4 feet high composed of 1:4:7½ concrete.

All exposed corners and edges of the concrete work are rounded to a 1-inch radius.

CHAPTER X.

SIGNAL TOWERS, WATER TANK SUPPORTS AND BUMPING POSTS.

SIGNAL TOWERS.

Railroads throughout the country are experiencing a period of architectural Renaissance. Structures which have in the past been built of temporary construction, apparently regardless of outward appearance, are being replaced by permanent buildings of artistic design. This is particularly true in the case of signal towers, the old unsightly and necessarily temporary wooden structures being superseded either by entire concrete or combination concrete and brick towers of pleasing appearance and permanent construction.

FIG. 93.—SIGNAL TOWER, NAUGATUCK, CONN., N. Y., N. H. & H. R. R.

NAUGATUCK JUNCTION TOWER, N. Y., N. H. & H. R. R. With the exception of the roof, which is of Ludowici Celadon tile on wooden rafters, this tower is of concrete construction throughout. The foundation and both ex-

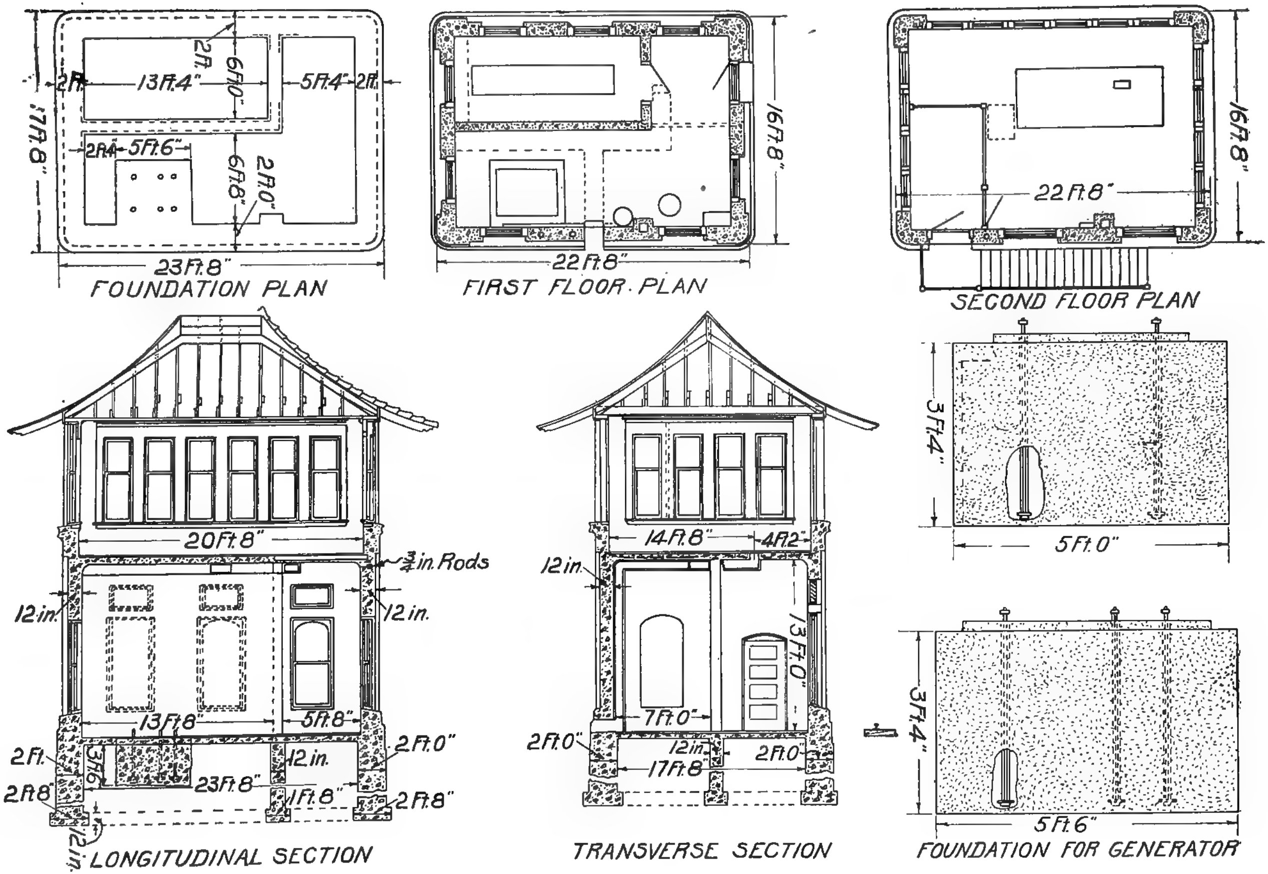


FIG. 94.—DETAILS OF CONSTRUCTION, NAUGATUCK SIGNAL TOWER, N. Y., N. H. & H. R. R.

terior and interior walls are of plain 1:3:5 gravel concrete, while the floors are of 1:2:4 gravel concrete reinforced with No. 16 2½-inch expanded metal. The general features of design and construction are shown very clearly by the drawings in Fig. 94.

As will be seen from the photograph in Fig. 93, the architectural treatment of the building is enhanced by the use of indented arches over the lower windows, and by a projecting ornamented belt course which runs around the entire building and serves as a lintel for the upper windows. The roof is designed along pagoda lines with a very pleasing result.

The tower was designed by the engineering department of the railroad and built by its building department in 1906.

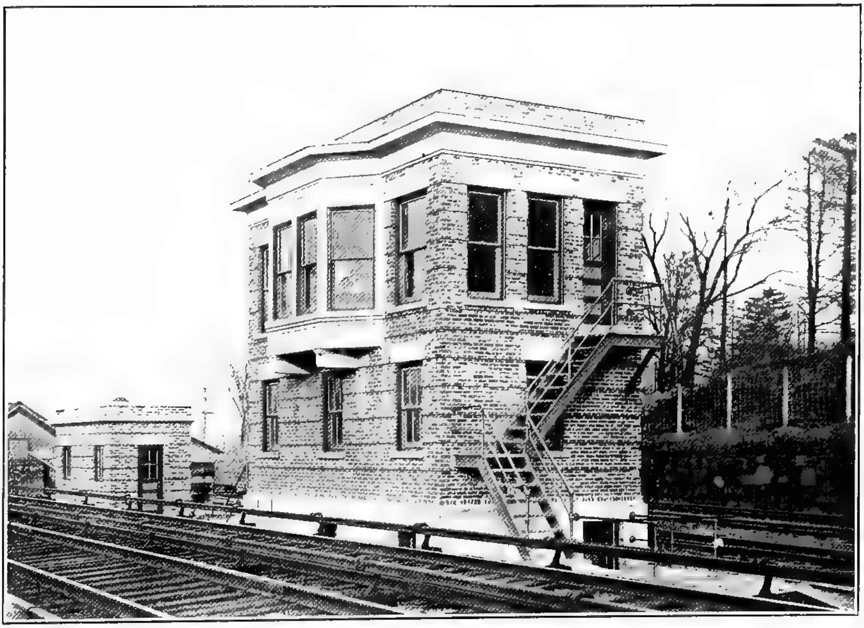


FIG. 95.—KINGSBRIDGE SIGNAL TOWER, N. Y. C. & H. R. R. R.

KINGSBRIDGE TOWER, N. Y. C. & H. R. R. R. The standard signal towers of the electric zone of the New York Central and Hudson River Railroad are combination brick and concrete structures, a typical example of which is shown by the photograph of the Kingsbridge Tower in Fig. 95. The footings and foundation walls below grade are of 1:4:7½ concrete, and the walls above grade up to the first floor level are of 1:3:6 concrete. All the sills and lintels, the coping, the overhanging bay window and supporting brackets

and the cornice are of 1:2:4 concrete, the details of construction of which are shown by the drawings in Fig. 96.

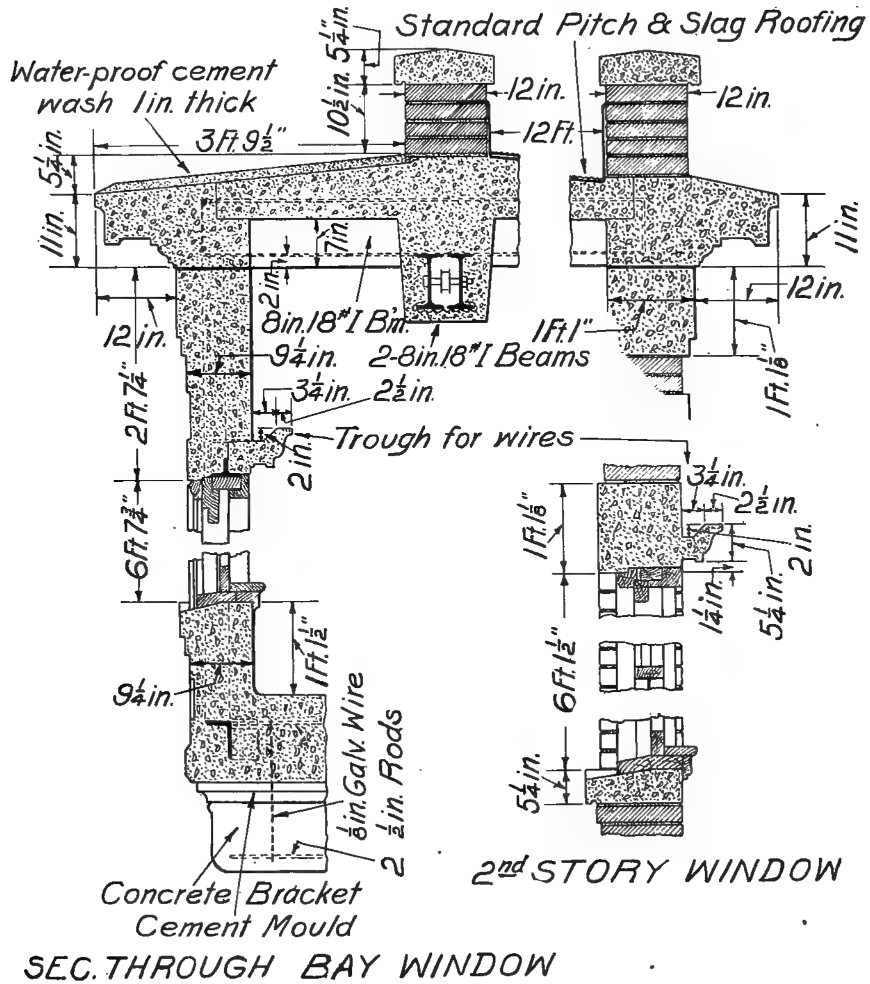


FIG. 96.—DETAILS OF CONSTRUCTION, KINGSBRIDGE SIGNAL TOWER, N. Y. C. & H. R. R. R.

The excellent finish of this work was obtained by floating the green concrete with water and rubbing it with a mortar brick composed of 1 part cement to 2 parts sand. The floor and roof construction consists of 1:2:4 concrete slabs, reinforced with ½-inch round rods, supported by steel I-beams.

GROVE ST. SIGNAL TOWER, D., L. & W. R. R. This tower, located about 250 feet west of Grove Street, Hoboken, is built entirely of reinforced

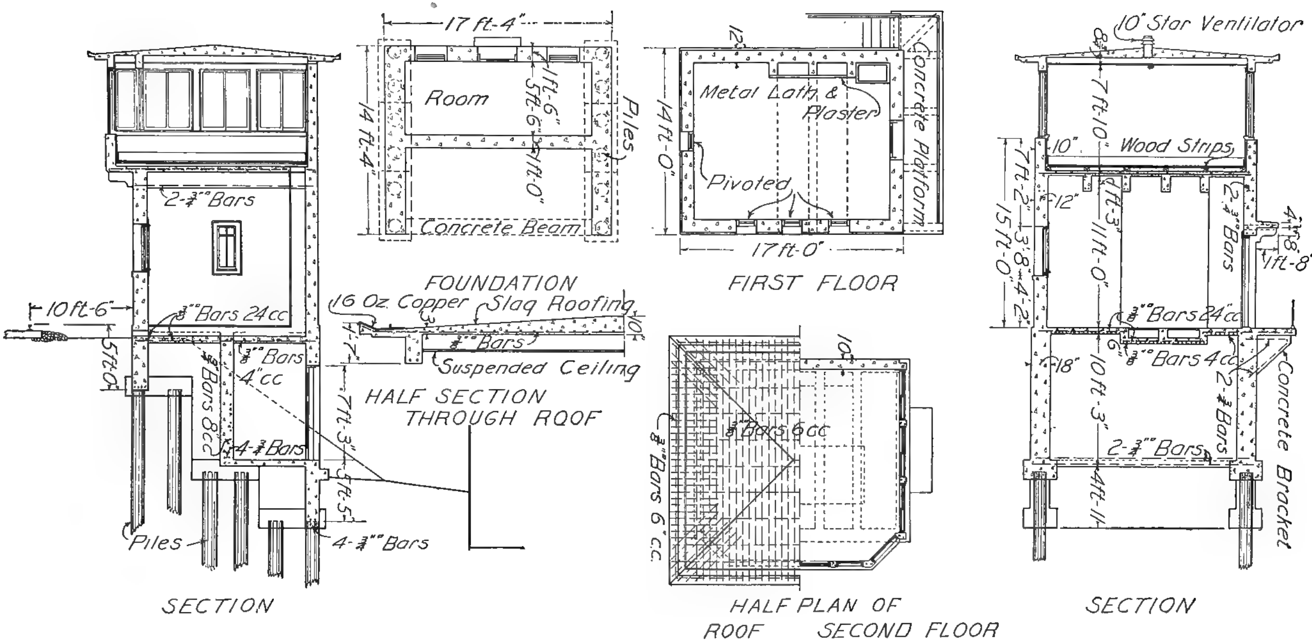


FIG. 97.—DETAILS OF CONSTRUCTION, GROVE ST. SIGNAL TOWER, D., L. & W. R. R.

concrete and was designed and constructed by the engineering department of the Delaware, Lackawanna and Western Railroad, Mr. Lincoln Bush, Chief Engineer, and Mr. F. J. Nies, architect. The general details and essential features of design and construction are shown in Fig. 97, while the photograph in Fig. 98 is of the finished structure.

FIG. 98.—SIGNAL TOWER, GROVE STREET, HOBOKEN, D., L. & W. R. R.

There are several interesting features of construction in connection with the tower which are somewhat out of the ordinary. The side walls rest on creosoted piles spaced 2 feet 8 inches apart, while the front and rear walls are carried by reinforced concrete girders spanning from side wall to side wall. At the first floor level there is a concrete platform leading to the iron stairs in the rear which is supported on reinforced concrete brackets cantilevering 3 feet from the side wall of the building. The roof, which overhangs 1 foot 10 inches, and appears from the ground to be flat, is a reinforced concrete slab pitching from a thickness of 3 inches at the walls to 10 inches at the center. With the exception of the overhang, which is flashed with 16-ounce copper, the concrete slab is covered with slag roofing.

The concrete for the entire building was mixed in the proportions of 1:2:4, and all exposed surfaces were rubbed.

In designing the tower a ratio of elasticity of 15 was assumed, and the con-

crete was figured at 600 pounds per square inch fiber stress, 500 pounds per square inch direct compression, and 50 pounds per square inch shear, while the steel was given a tensile stress of 16,000 pounds per square inch.

WATER TANK SUPPORTS.

Owing to its strength, rigidity and resistance to fire and decay, reinforced concrete is aptly suited for the construction of water tank supports.

In addition to the support described below, other examples of this form of construction are illustrated among the miscellaneous photographs in the back of the book.

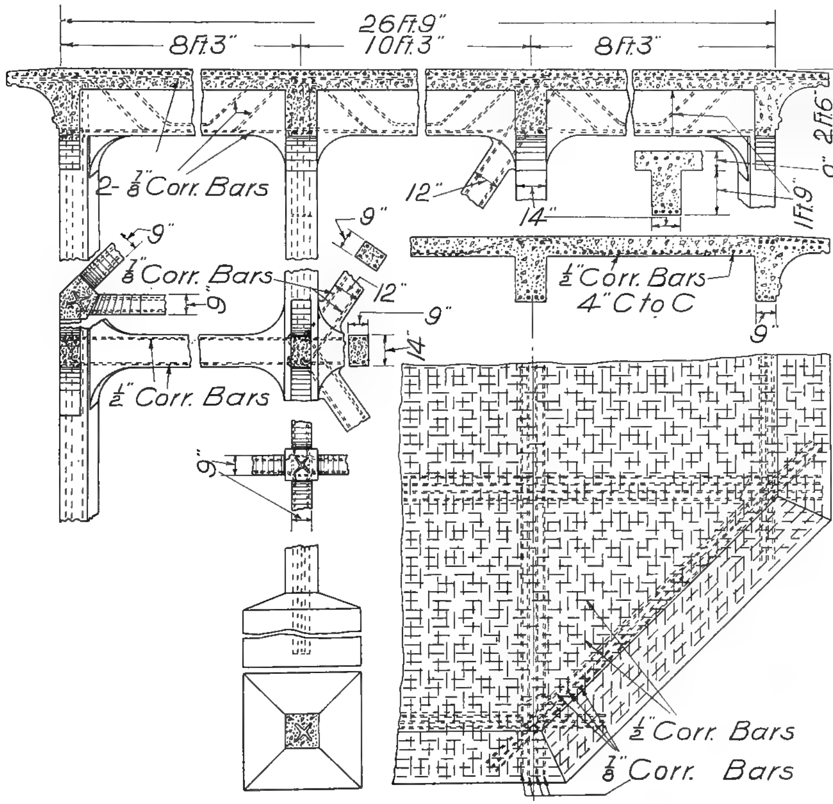


FIG. 99.—DETAILS OF CONSTRUCTION, WATERBURY WATER TANK SUPPORT.

WATER TANK SUPPORT AT WATERBURY, N. Y., N. H. & H. R. R.

This tank support, octagonal in form, is 30 feet 9 inches wide, with the platform carrying the water tank 40 feet above the ground line. It is designed to carry a 55,400 gallon wooden tank.

The essential details of design and construction are shown clearly by the drawings in Figs. 99 and 100, while the photograph in Fig. 101 is of the finished support.

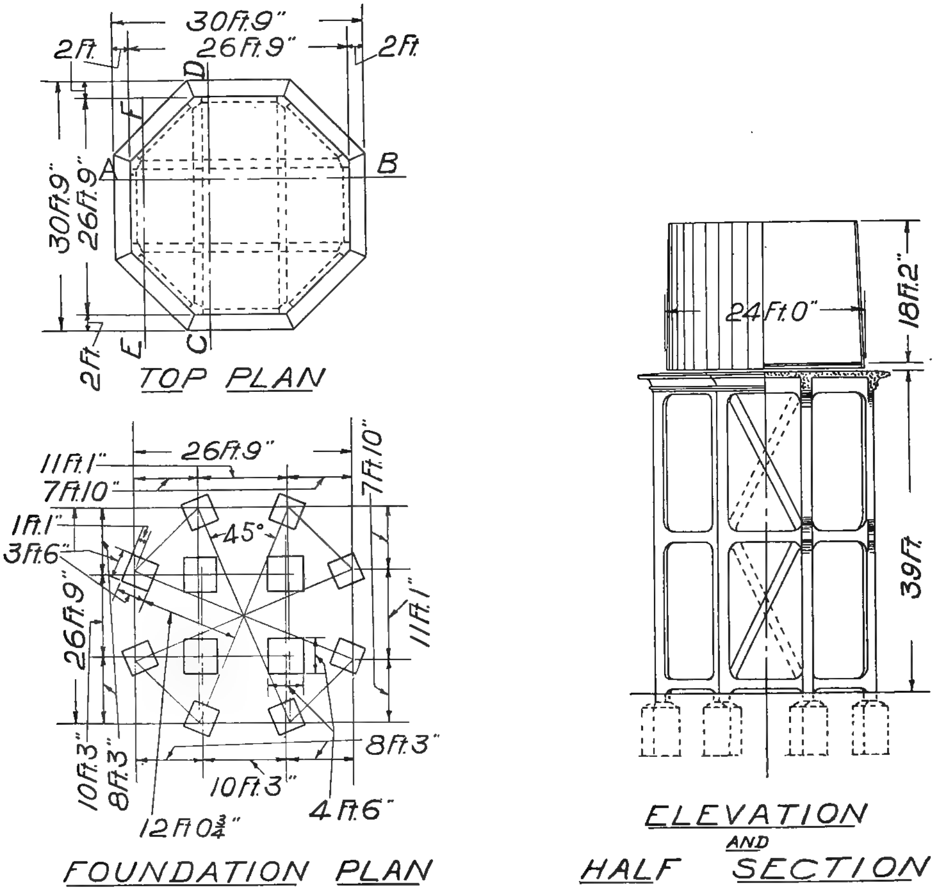


FIG. 100.—PLAN, HALF SECTION AND HALF ELEVATION WATER TANK SUPPORT, N. Y., N. H. & H. R. R.

The method of reinforcing the supporting columns presents a rather unique and interesting feature. This reinforcement consists of two 95-pound third rails placed back to back and riveted every 3 feet, making a section in the form of a star strut.

The platform which is 9 inches thick is reinforced with ½-inch corrugated bars 4 inches on centers in both directions while the beams and diagonal braces are reinforced with ⅞-inch corrugated bars bent and hooked as shown in Fig. 99.

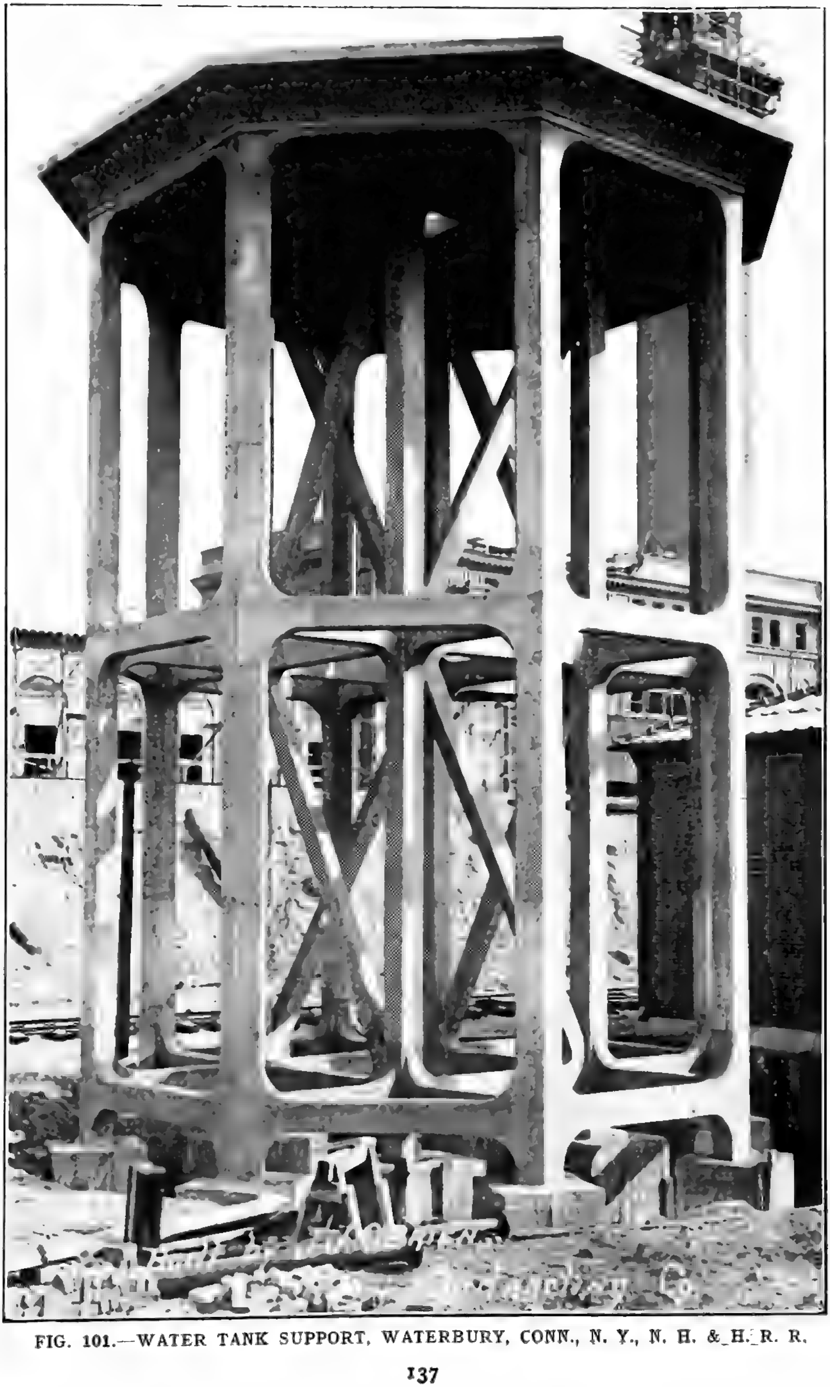


FIG. 101.—WATER TANK SUPPORT, WATERBURY, CONN., N. Y., N. H. & H. R. R.

Concrete for the support was mixed in the proportions of 1 part Portland Cement to 2 parts sand and to 4 parts screened gravel.

The structure was designed by the Engineering Department of the railroad and built by the O'Brien Construction Company of Waterbury, Conn., during the fall of 1908.

FIG. 102.—CONCRETE BUMPING POSTS, D., L. & W. R. R.

BUMPING POSTS.

A bumping post, to insure safety against rotating or breaking down under constant buffing, must be constructed so as to be anchored in the earth direct rather than attached to the track itself, as is the case with practically all of the patented posts now in use on railways in this country. By the use of concrete, bumping posts can be constructed economically so as to meet the conditions of stability and permanence.

STANDARD CONCRETE BUMPING POSTS, D., L. & W. R. R. This post is given in detail by the drawings in Fig. 103, while the photograph in Fig. 102 shows three of the posts in service at Newark, N. J. As will be seen from the drawings, the buffer block is of granite and the reinforcement of the post

consists of 80-pound rails connected with 1¼-inch tie rods. The footing of the post is carried down to solid foundation.

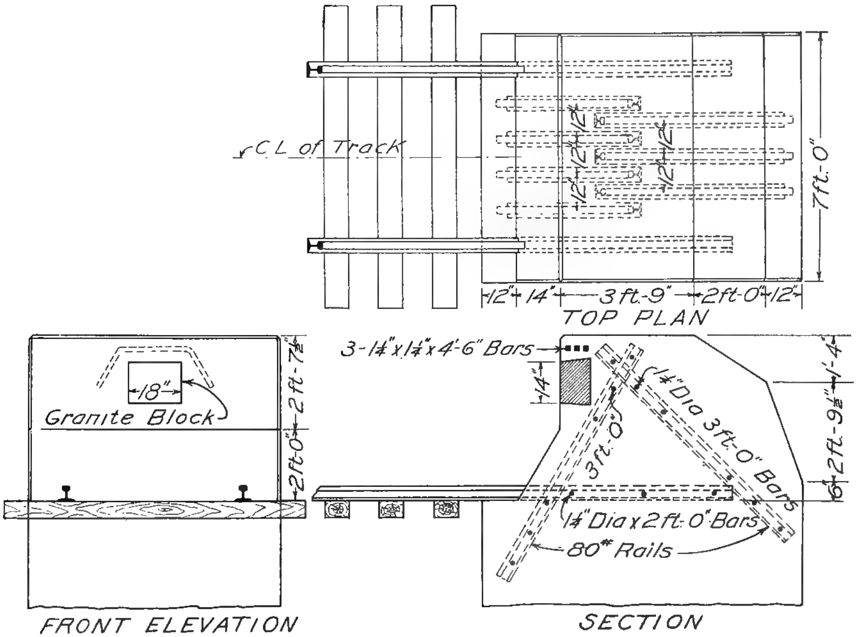


FIG. 103.—STANDARD CONCRETE BUMPING POSTS, D., L. & W. R. R.

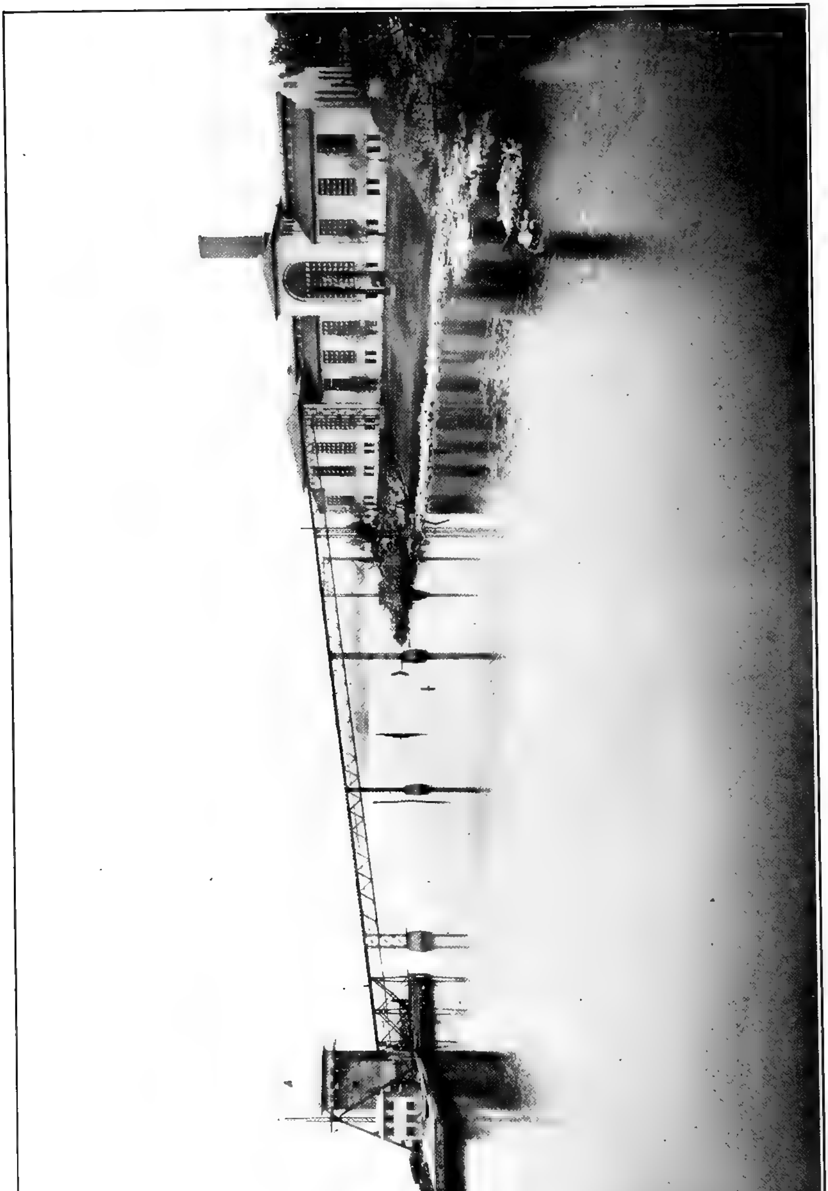


FIG. 104.—COS COB POWER PLANT FROM RIVER.

CHAPTER XI.

POWER STATIONS, SHOPS, WAREHOUSES AND GRAIN ELEVATORS.

POWER STATIONS.

The electrification of railroad systems, which bids fair to be a thing of the near future, will necessitate the construction of a large number of power stations along the lines of the railroads adopting this form of motive power.

Concrete construction in addition to its low first cost, facility of erection and fireproof character is especially adapted to the building of power plants on account of its inherent strength, resistance to vibrations and freedom from deterioration.

The New York, New Haven and Hartford Railroad, one of the earliest pioneers in the field of heavy electric traction, has installed electric equipment on its lines from Woodlawn, N. Y., to Stamford, Conn., with the power station for this twenty miles of road located at Cos Cob, about three miles from Stamford. This power house described below is of concrete construction and is a noteworthy example of the pleasing appearance which can be given to a purely utilitarian structure by engineers who pay special attention to the architectural treatment of their designs.

COS COB POWER PLANT, N. Y., N. H. & H. R. R. The power house is located at Cos Cob, three miles west from Stamford, on the Mianus River, about a mile from Long Island Sound. The engineers in charge of the design and construction of the plant adopted the Spanish Mission style of architecture for the exterior of the building, with a very pleasing result. The interior is divided into a turbine room 60 feet wide by 112 feet long, with a switchboard occupying an additional space of 25 feet by 110 feet and a boiler room 160 feet long by 110 feet wide.

The photograph in Fig. 105 shows the track side, while Fig. 104 is of the water side of the power house.

The foundations, column footings and walls up to the water table are monolithic concrete mixed in the proportions of 1 part Atlas Portland Cement, 3 parts sand and 5 parts 2-inch crushed granite. All exposed surfaces of the walls have a bush-hammered finish. For the water-table, window

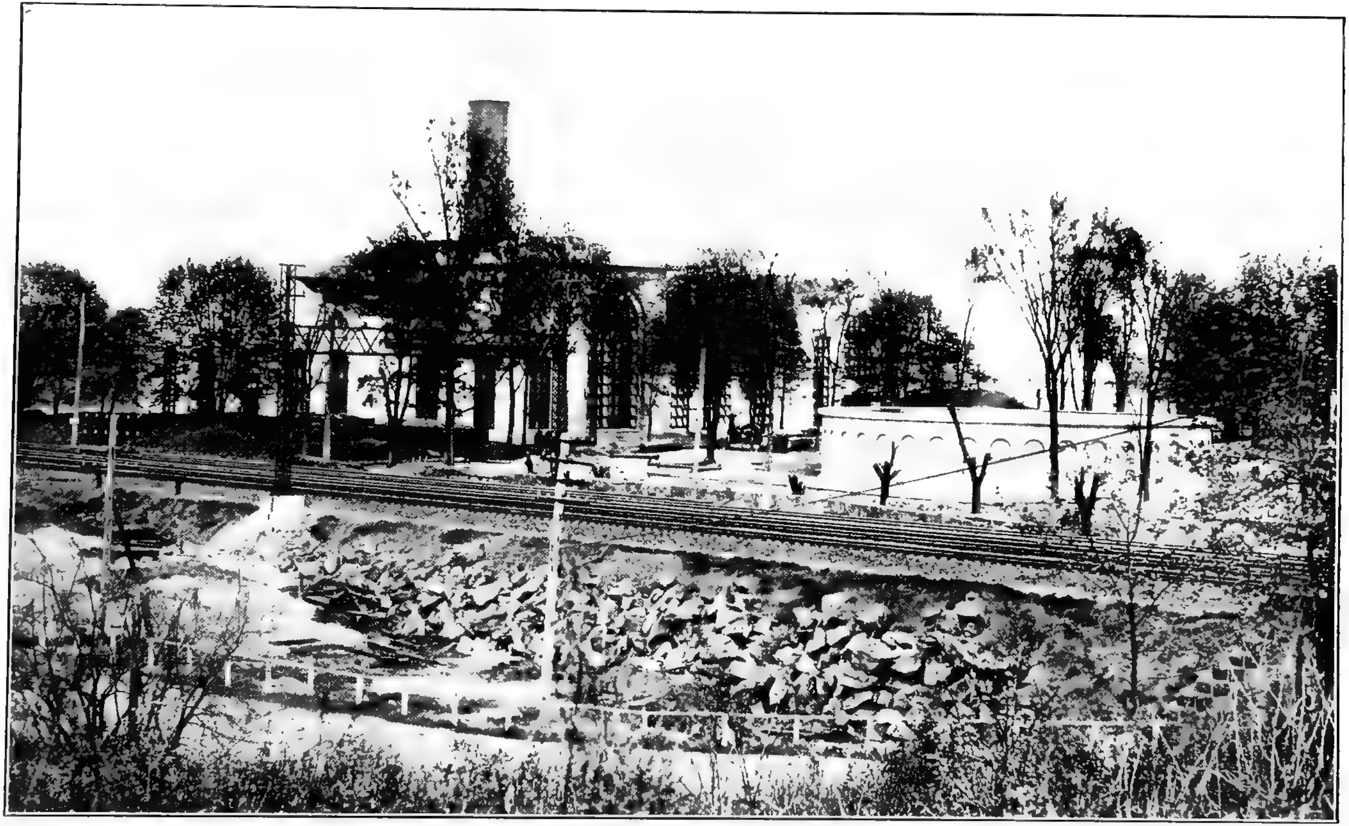


FIG. 105.—COS COB POWER PLANT FROM TRACK.

arches, coping and window sills, monolithic blocks are used. These blocks, are built in special shapes and are made of concrete of the same proportions as the other monolithic work, and have the inner and outer surfaces faced with a mixture of 1 part cement to 2 parts sand.

The walls above the water-table are of hollow blocks, 10 in. by 12 in. by 24 in., composed of a mixture of 1 part cement, 3 parts sand and 3 parts 1¼-inch crushed granite, faced on the exterior surface with a mixture of 1 of cement to 2 of sand, and where the inner surface of the wall is exposed with a mixture of 1 part cement to 4 parts sand. All the window lintels were cast in place, and consist of 1:3:5 concrete reinforced with two ¾-trussed bars.

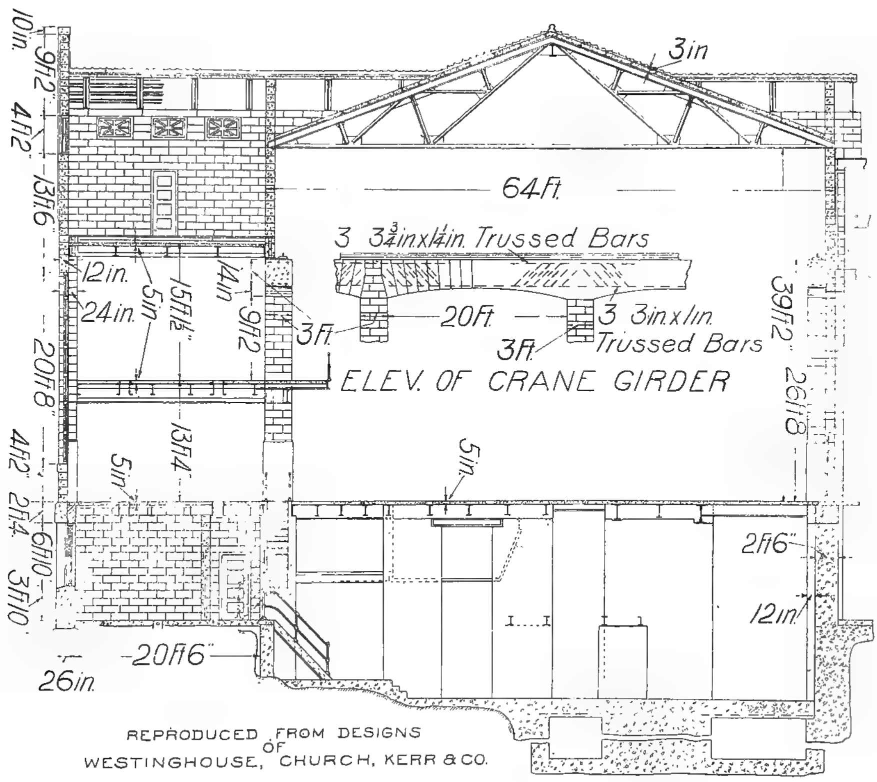


FIG. 106.—CROSS SECTION THROUGH TURBINE ROOM, COS COB POWER PLANT.

In designing the structural features of the building, the following live loads per square foot were used: Coal bin floor, 550 pounds; engine room and gallery floors, 400 pounds; boiler room floor, 340 pounds; fan room floor, 200 pounds; roof, 30 pounds. With the exception of the roof slabs, which are of cinder concrete, the stresses allowed for the concrete are 600 pounds per square

inch extreme fiber stress, 400 pounds per square inch direct compression, and 60 pounds per square inch shear, and for the steel a tensile stress of 16,000 pounds was assumed.

The columns in the boiler room are of structural steel, but all other columns in the building are composed of concrete blocks made by filling the cored air spaces of the hollow blocks with concrete of the same mixture as the blocks themselves. Over the turbine room where there are no steel columns the steel roof trusses are carried by the concrete block wall, the blocks being solid for several courses below trusses to properly distribute the load. Over the

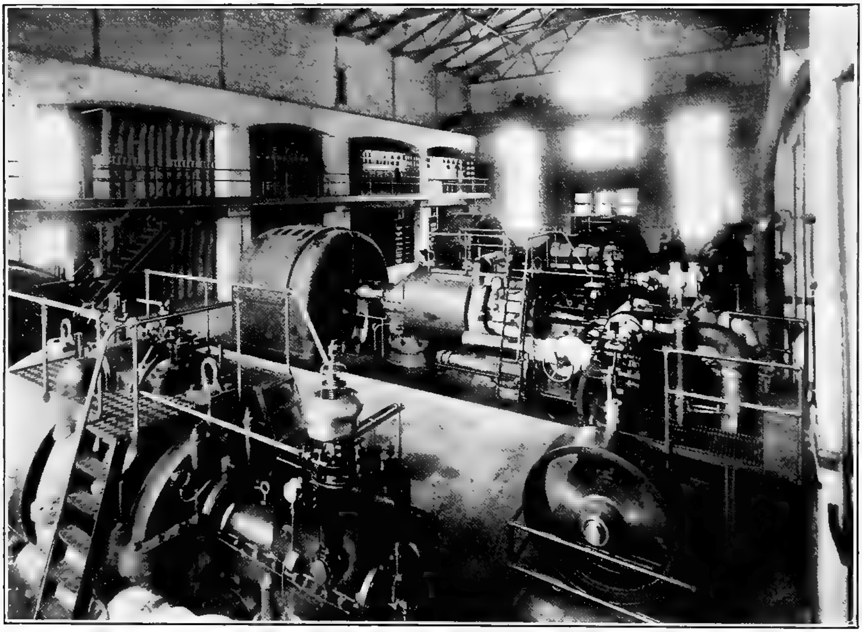


FIG. 107.—TURBINE ROOM, COS COB POWER PLANT.

boiler room the trusses are supported in the same way and also by the interior steel columns.

The front of the switchboard gallery, at one end of the turbine room, is carried on concrete block columns, which also support a reinforced concrete girder forming one of the crane runways, which carry an electric traveling crane, provided with two 17½-ton trolleys. The other crane runway is formed by a similar girder built into the partition wall between the engine room and boiler room, and is carried by pilasters formed in this wall. These girders furnish a rather unique feature, for while they are essentially concete girders

36 by 36 inches reinforced with trussed bars, they are built with the bottom slightly arched and the sides and bottoms ribbed to imitate keystone and voussoirs, the whole giving the appearance of a segmental arch. The girders are shown clearly in the photograph of the turbine room in Fig. 107 and by the drawings in Fig. 106, which are of a cross section taken through the turbine room.

With the exception of the basement floor, which is 1:3:5 concrete laid directly upon the foundation rock, the floor system consists of concrete slabs, reinforced with twisted steel rods, carried on the top flanges of I-beams. These slabs were mixed in the proportions of 1 part cement, 3 parts sand and 5 parts ¾-inch broken stone with a 1-inch granolithic finish applied before the underlying concrete had time to dry. After the floors had dried out they were given two coats of linseed oil and lampblack. In the engine room the floor finish is carried up at the side walls and columns to form a base 10 inches high and 1¾ thick for a 6 foot wainscoting of Faience tile. Above this wainscoting the walls are unfinished except for a cement wash.

The roof, which has a pitch of 4½ inches per foot, is of 1:2:4 cinder concrete laid between 3-inch 5½-pound I-beam purlins 3 feet on centers, and is finished on the exterior with red Ludowici interlocking tiles set on 1 inch by 2 inch strips 24 inches on centers, and secured thereto by means of staples and copper wire. Between the tiles and the concrete there is one thickness of tarred paper.

A self-supporting steel stack 13 feet 6 inches in diameter and 46 feet high is carried by the steel columns which support the fan room floor, thus leaving the space below, in the boiler room, entirely clear.

Work on the power house was started Feb. 3d and steam was turned on Nov. 4, 1906. The construction plant consisted of one ¾ and one 1½-yard mixers, a stone crusher, 3 boom derricks, a temporary power plant, buckets, etc., and two block machines. The material excavated was a gneiss rock, and furnished after crushing and screening all the broken stone for the building, and a sufficient quantity of screenings to take the place of sand for the exterior walls. For the wall forms 2-inch matched spruce was used and for the floor and roof slab forms 1-inch matched spruce. The monolithic blocks which were molded in pine forms, well greased, were mixed very wet, and after the removal of the forms were stored under canvas 24 hours and then left in the open for three weeks. After the hollow blocks were turned out of the machine they were cured in the same manner.

The plant was designed, erected and equipped by the Westinghouse, Church-Kerr Company under the direction of Mr. E. H. McHenry, Vice-President of the New York, New Haven and Hartford Railroad.

The same advantages which reinforced concrete possesses over other materials for the construction of power houses are equally enjoyed by it as a material for shop and warehouse buildings for railway purposes.

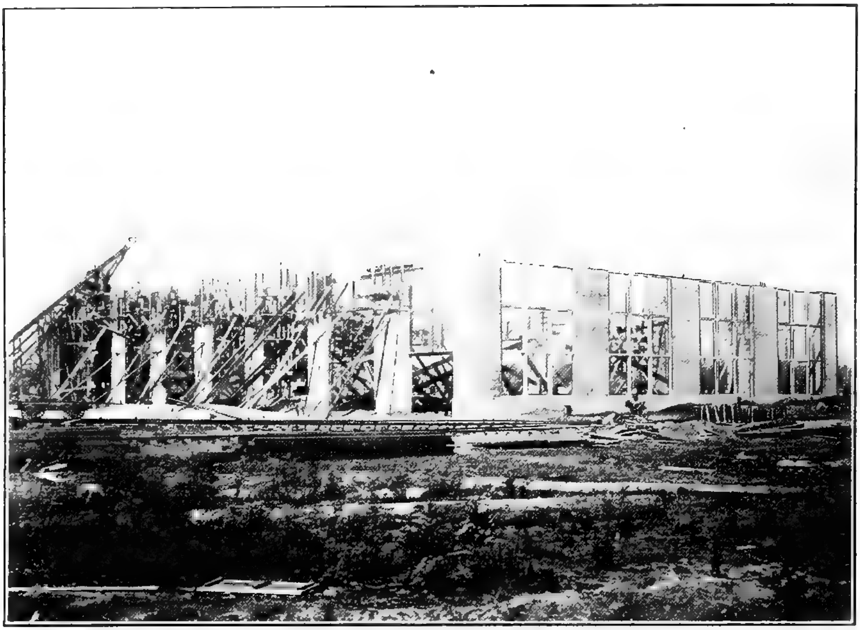


FIG. 108.—BOGALUSA SHOPS DURING CONSTRUCTION, N. O. & G. N. R. R.

The field of reinforced concrete in shop and warehouse construction is so vast that it is impossible to even attempt to cover it in this chapter, but the reader is referred to "Reinforced Concrete in Factory Construction," published by The Atlas Portland Cement Company, as a more complete treatise on the subject.

In addition to the structures described and illustrated below, there are a number of shops, freight sheds, warehouses and inspection sheds shown among the miscellaneous photographs in the back of the book.

N. O. & G. N. R. R. SHOP AND STORE HOUSE, BOGALUSA, LA.—The photograph in Fig. 108 shows one of the shops during construction and Fig. 109 is of the finished store house of the New Orleans and Great Northern Railroad at Bogalusa, La. With the exception of the roof, these buildings

are of concrete construction throughout. They were designed and erected by the Arnold Company of Chicago in 1907.

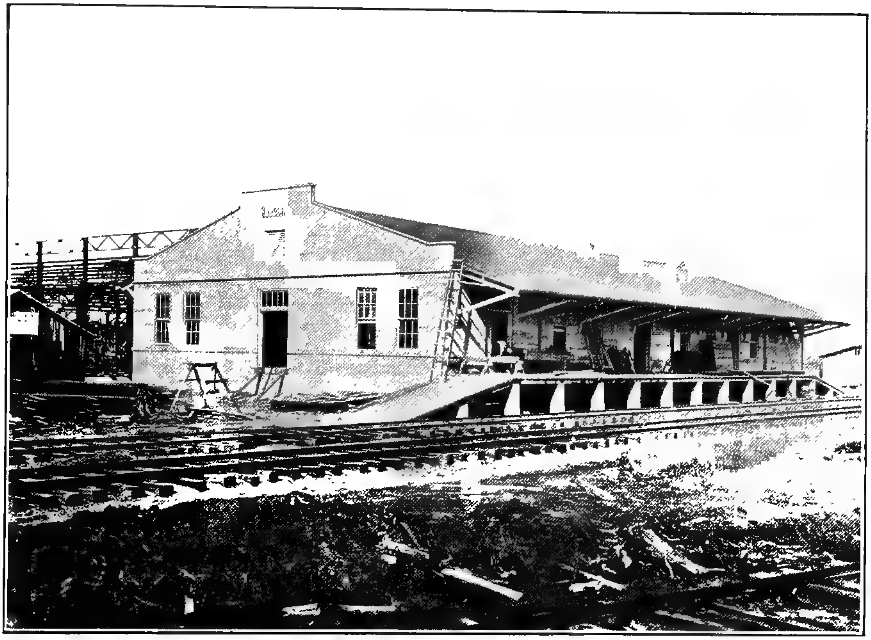


FIG. 109.—STORE HOUSE, BOGALUSA, LA., N. O. & G. N. R. R.

MOTT HAVEN CAR SHOPS, N. Y. C. & H. R. R. R.—The Mott Haven shops are 250 feet long, 43 feet 10 inches wide, and, as will be seen from the photograph in Fig. 110, they are built in alternate high and low bays, the former 25 feet high and the latter 19 feet 4 inches. As windows are provided in each side of the high bays above the roof of the low ones, this construction takes the place of the ordinary saw-tooth roof.

In general, the buildings consist of 2½-inch cement mortar curtain walls reinforced with truss metal lath, No. 28 gage, resting on a concrete foundation wall rising 4 feet above the ground level. The roof is carried on light angle trusses supported by I-beam columns placed every 16 feet 8 inches at the division between the adjoining high and low sections. Between the columns and window frames steel girts are placed to form a support for the truss metal lath reinforcement of the walls.

The metal lath was kept in place and held rigidly by means of temporary 1 by 1 inch angles spaced about 2 feet apart. The mortar, which was mixed

in the proportion of one part Atlas Portland Cement to three parts sand, was placed in the same manner as plaster for an ordinary wall.

The shops were designed and erected in 1908 under the supervision of the engineering department of the New York Central & Hudson River R. R., Mr. G. W. Kittredge, Chief Engineer. The Truss Metal Lath Company, New York City, furnished the reinforcing material and built the walls of the building.

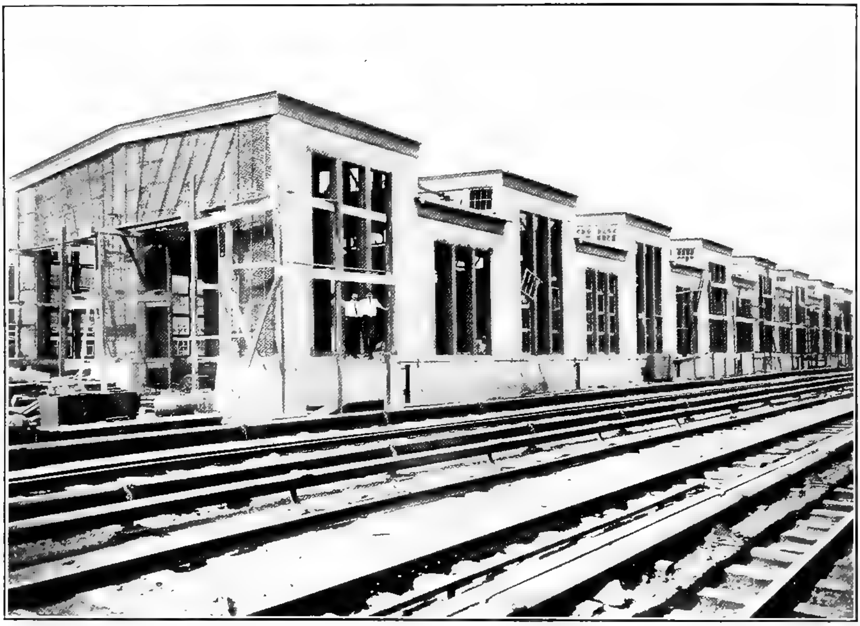


FIG. 110.—CAR SHOPS, MOTT HAVEN, N. Y. C. & H. R. R. R.

NEWARK WAREHOUSE, C. R. R. of N. J.—This mammoth seven-floor warehouse, a photograph of the track side of which is shown in Fig. 111, is 360 feet long with a width varying from 130 to 165 feet, and has a storage capacity of about 1,200 carloads of freight. The first floor is devoted to teaming, the second to the freight tracks, and the basement and four top floors to storage.

In general, the building consists of a steel frame and concrete walls, with steel columns and girders carrying floor slabs of reinforced concrete. Owing to the presence of quicksand, an exceptionally wide spread of footings was required, which resulted in the engineers making the foundation one continuous plate of concrete 15 inches thick reinforced with extra heavy expanded metal.

The walls, which are embellished with rustications, moldings, dentils and cornices, are 20 inches thick to the second story, 16 inches thick to the third story, and 12 inches thick from there up to the top. The reinforcement for the walls consists of expanded metal and ¾-inch rods laid horizontally about 4 feet apart.

The concrete for the walls, floor slabs, column covering and roof slabs, was mixed in the proportions of one part Atlas Portland Cement, to 2 parts Cowe Bay washed sand, to 4 parts ¾-inch crushed stone.

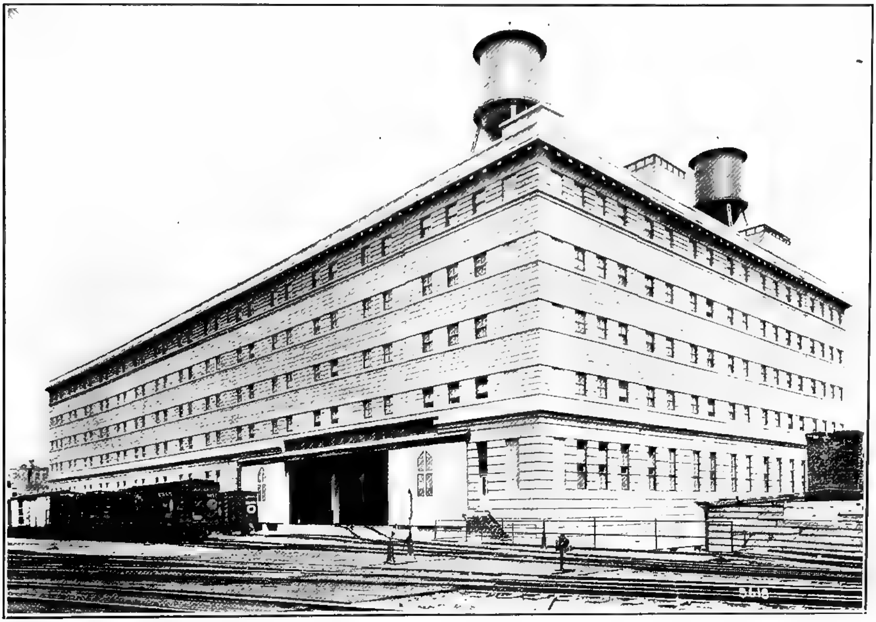


FIG. 111.—NEWARK WAREHOUSE, C. R. R. OF N. J.

The warehouse was designed and constructed under the general direction of Mr. Jos. O. Osgood, Chief Engineer of the C. R. R. of N. J., by the John W. Ferguson Co., Paterson, N. J., in 1907.

PORT MORRIS BOILER HOUSE, D., L. & W. R. R.—The photograph in Fig. 112, page 150, shows a boiler house of heavy concrete construction built at Port Morris, N. J., for the Deleware, Lackawanna & Western R. R.

LOADING PLATFORM, SIOUX CITY, IA.—In connection with warehouses and storage sheds, the construction of loading platforms is of special interest. The photograph in Fig. 113, page 150, shows a reinforced concrete platform 164 feet long and 14 feet wide, which was constructed in 1908 at a cost of $2,500.

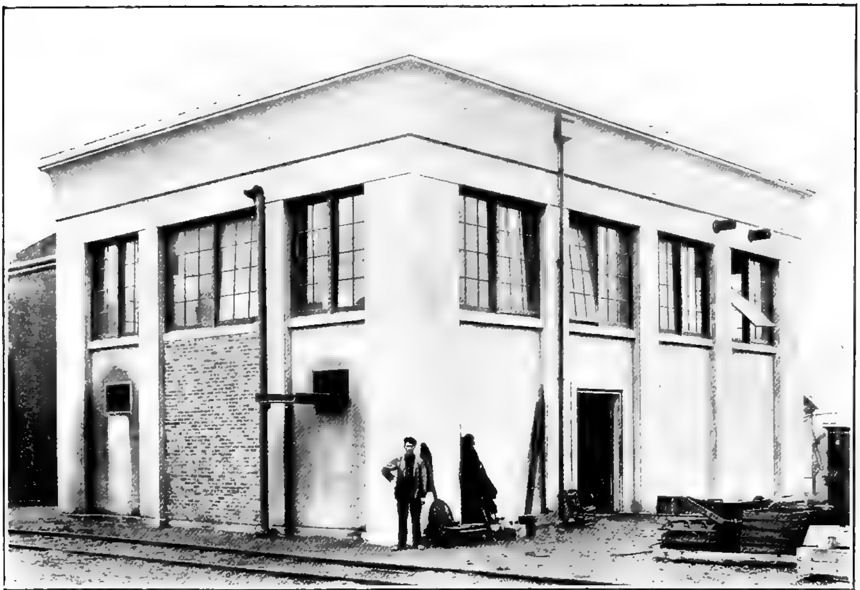


FIG. 112.—PORT MORRIS BOILER HOUSE, D., L. & W. R. R.

FIG. 113.—LOADING PLATFORM, SIOUX CITY IA.

GRAIN ELEVATORS.

Reinforced concrete is especially adapted to the construction of grain elevators or other structures to be used for the storage of grain on account of its being absolutely proof against fire, water or dampness, dust and vermin; which are all important and essential qualities of the ideal grain elevator.

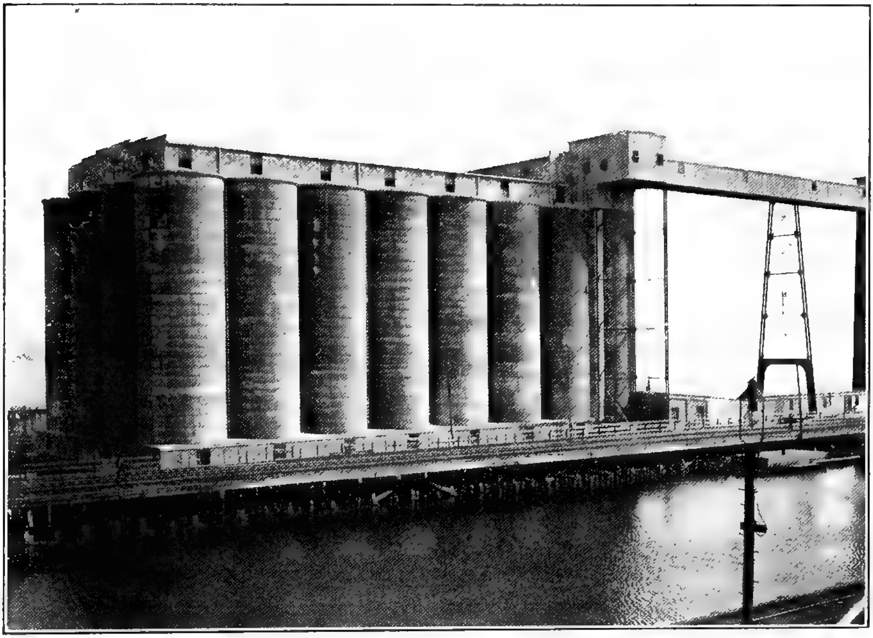


FIG. 114.—TYPICAL CONCRETE GRAIN ELEVATOR.

Grain elevators may be grouped into two classes according to the arrangement of the bins and elevating machinery; viz., elevators which are self-contained, with all the storage bins in the main elevator or working house; and elevators consisting of a working house which contains the elevating machinery and storage bins connected with the working house by conveyors Reinforced concrete elevators are commonly built of the latter type, with a working house that is generally rectangular in shape with either square or circular bins connected with the independent storage bins, which are usually circular. The photograph in Fig. 114 is of a reinforced concrete elevator of the type built by the James Stewart & Co., of Chicago.

In elevators of this type the storage bins are reinforced both horizontally and vertically. The horizontal reinforcement is either single when it is placed

in the center of the wall, as in Fig. 115, or double when the bars are placed near the surface. This reinforcement may be continuous, rising from the bottom to the top as a spiral, in which case high steel wire is generally used, or may

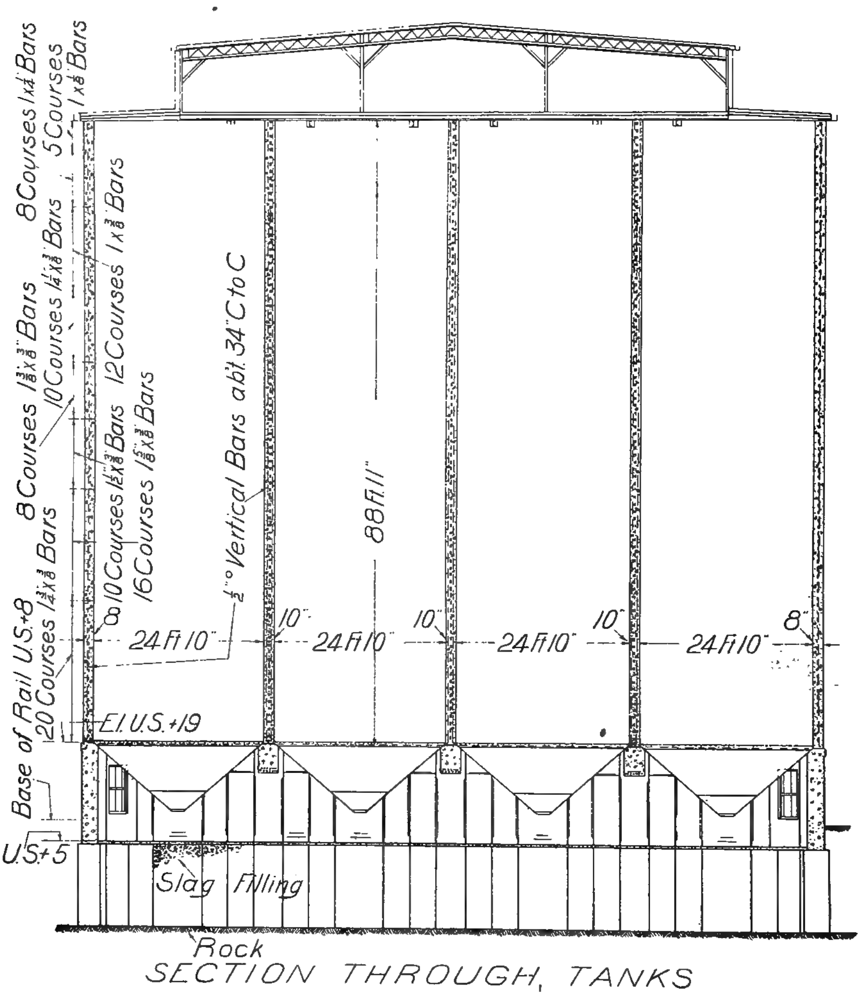


FIG. 115.—CROSS SECTION OF TYPICAL REINFORCED CONCRETE GRAIN ELEVATOR.

be placed in separate rings, as in Fig. 117. The vertical reinforcing bars are equally spaced, and are wired or clamped to the horizontal rods at intersections.

The horizontal reinforcement is generally designed to take all the tensile stresses resulting from the pressure of the grain, while the vertical reinforce-

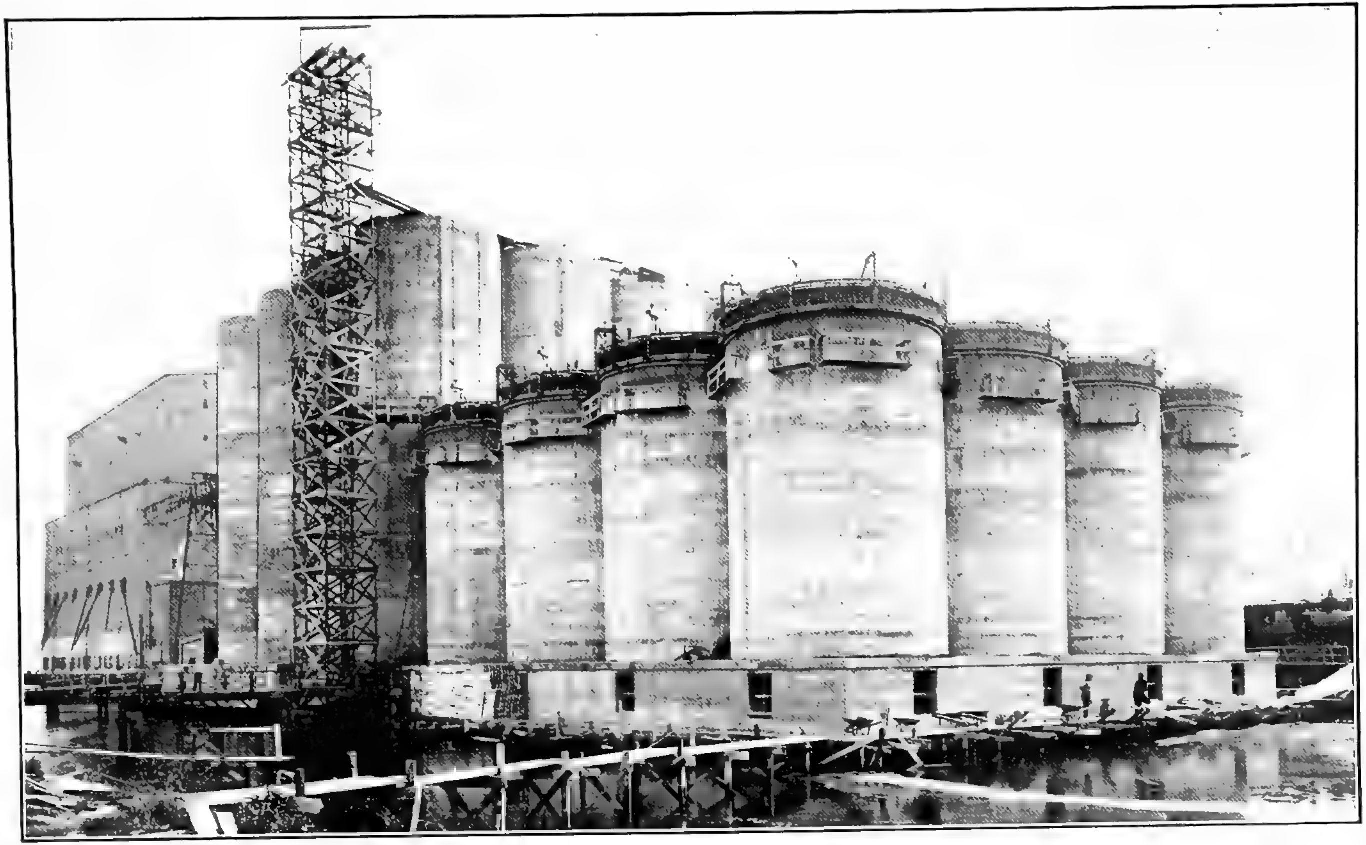


FIG. 116.—GRAIN ELEVATOR BEING CONSTRUCTED.

ment carries the load between the horizontal reinforcement, and takes its proportion of the vertical load. The walls have a negative bending moment at the points of horizontal reinforcement, and a positive bending moment halfway between the horizontal reinforcement. The pressure on any horizontal section equals the weight of the wall plus the weight of the grain carried by the walls, and this pressure is carried by both the concrete and the steel.

While the space here is too limited to go into the discussion of the theory

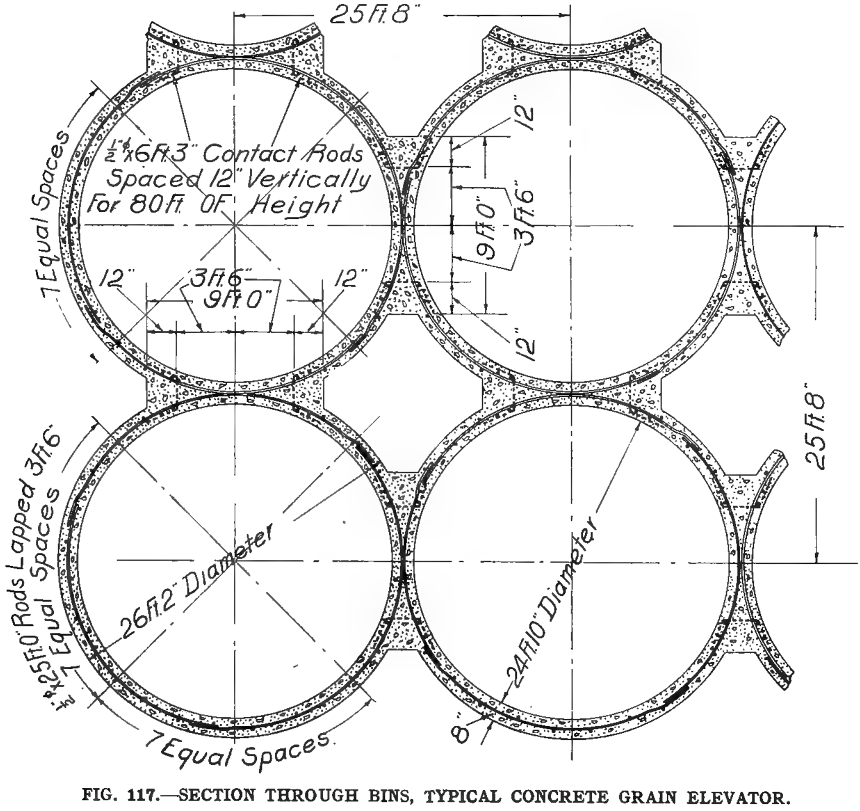


FIG. 117.—SECTION THROUGH BINS, TYPICAL CONCRETE GRAIN ELEVATOR.

of the pressure in grain bins or to give the methods employed in designing the structural features of reinforced concrete grain elevators, the reader is referred to "The Design of Walls, Bins and Grain Elevators," by Milo S. Ketchum, as a complete treatise on the subject.

Among the miscellaneous photographs in the back of the book are shown a number of reinforced concrete grain elevators of different types.

CHAPTER XII.

STORAGE RESERVOIRS.

The advent of power construction into the field of railroad engineering incidentally introduces another problem for railroad engineers in the subject of storage reservoirs for supplying these plants with water.

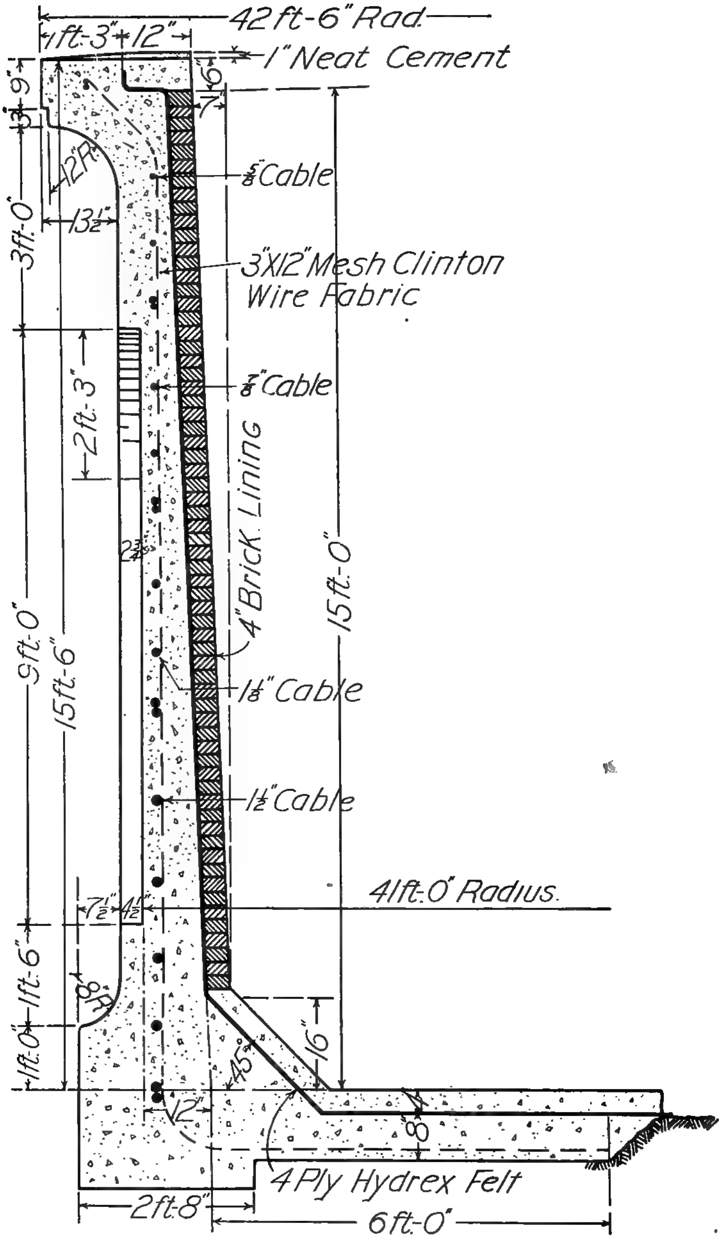
Reinforced concrete has been used extensively in the construction of reservoirs and when properly designed and constructed is a most suitable material on account of its durability and adaptability to lighter design than common masonry. For large or small tanks it is usually cheaper than steel and requires no repairs.

Reservoirs are built most economically of circular form, and all the tensile stresses must be taken by the steel hoops.

In buildng water tanks, the materials for the concrete must be very carefully proportioned so as to give a water-tight wall and the stone should be of such size that a good surface can be easily obtained. The proportions used to resist the percolation of water usually range from 1:1:2 to 1:2½:4½, the most common mixture being 1:2:4.

The concrete should be mixed so that it will entirely cover the reinforcing metal and flow against the form. It is absolutely essential that the concreting for the entire tank should be done in one operation, or else that the surface be specially prepared and treated to make water-tight joints.

COS COB STORAGE RESERVOIR.—In connection with the power plant of the New York, New Haven & Hartford R. R. at Cos Cob, Conn., described in Chapter XI, there is a 564,000 gallon reinforced concrete storage reservoir 80 feet in diameter and 15 feet deep. The architectural treatment of the exterior of the reservoir is in keeping with that of the power house and presents a very attractive appearance. As will be seen from the photograph in Fig. 119 and the section in Fig. 118, the wall has a cornice projecting 13½ inches and a base 7½ inches, while the flat space between is relieved with a series of forty arched indented panels. To further the effect of these arched panels, the face of the concrete of the indented surface is roughened, and the remainder of the exterior is given a smooth cement mortar finish.



REPRODUCED FROM DESIGNS OF WESTINGHOUSE, CHURCH, KERR & CO.

FIG. 118.—SECTION THROUGH WALL, COS COB STORAGE RESERVOIR

All the concrete was mixed in the proportions of 1 part Atlas Portland Cement, 3 parts sand and 5 parts 3/4-inch crushed granite. The wall is reinforced circumferentially with the cast steel transmission rope, varying in diameter from 1 1/2 inches at the base to 5/8 inches at the top, forming a continuous spiral with 12 foot splices made with 16 clips where the ends of different sizes of cable are joined. Wired to the inside of this rope spiral is a continuous sheet of 3 by 12-inch mesh wire cloth, placed in vertical

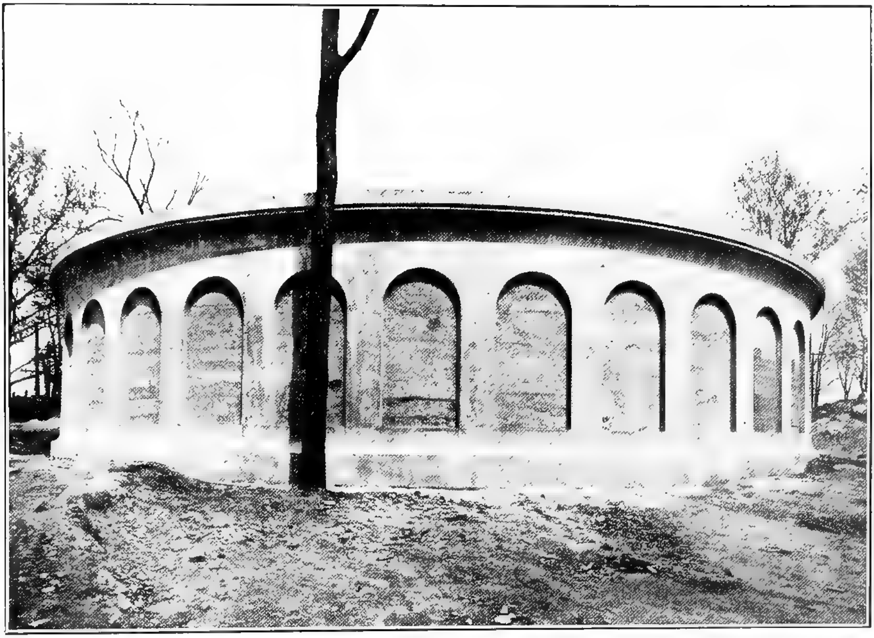


FIG. 119. COS COB STORAGE RESERVOIR, N. Y., N. H. & H. R. R.

strips and extending 6 feet into the floor of the reservoir. The wall and floor is waterproofed with 4-ply felt cemented together with a patented compound. On the floor of the tank a 4-inch protective covering of concrete was laid on top of the waterproofing, and carried up the wall 16 inches at an angle of 45°, to form a footing for a 4-inch lining of brick laid up in cement mortar that protects the waterproofing coat of the wall. The dimensions and general features of design of the reservoir are clearly shown in Fig. 118.

A 10-inch inlet and a 12-inch outlet pipe enter through the floor of the tank, and where they pass through the waterproofing, watertight connections are secured by clamping a sheet of soft copper between two flanged screw sleeves, as shown in Fig. 120. About a foot outside the reservoir wall these

pipes run into a concrete valve chamber 11 feet 4 inches long, 5 feet 8 inches wide, and 5 feet 3 inches high, in the top of which is a 30-inch manhole having an American Brake Shoe and Foundry Company's standard manhole frame and cover. A 3-inch steam pipe runs from the power house through the valve chamber and into the tank where it is carried half way across the floor on small brick piers 6 feet on centers. This pipe has a perforated upturned end so as to keep the water above the freezing point in cold weather.

In building the tank, the forms for the exterior wall were erected complete from the foundations to the coping. The spiral rope reinforcing was then hung on screw hooks driven into the inner surface of these forms and the

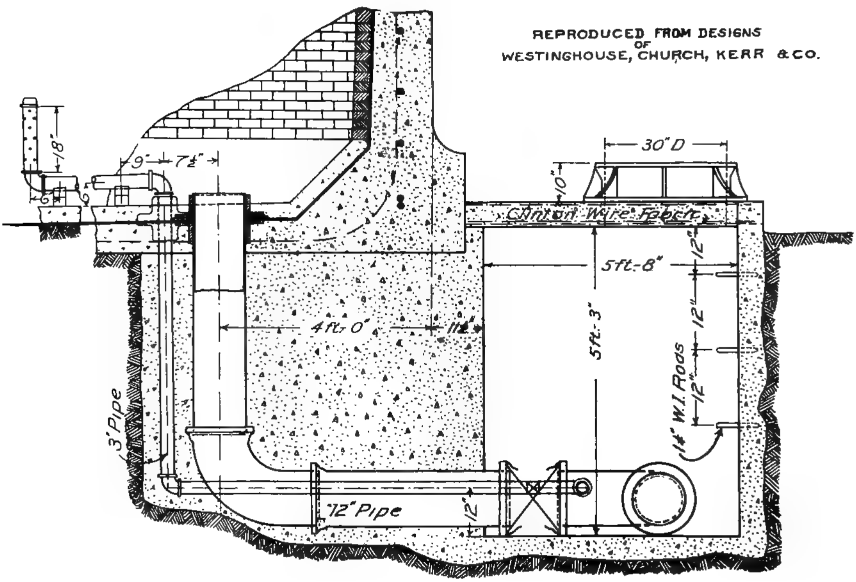


FIG. 120.—SECTION THROUGH VALVE CHAMBER, COS COB STORAGE RESERVOIR.

wire cloth was wired to the spiral. The inside forms were built up a few feet at a time, and were wired through the vertical supports to the outer forms. The concrete was mixed in a ¾ yard rotary mixer located just outside the reservoir, and was carried inside in 1 yard skips by a guyed derrick placed in the center of the tank and operated by a hoisting engine standing outside. The derrick cables were run through holes in the wall which were filled in after the forms were removed. Two weeks after concreting the walls the forms were removed, the derrick taken out, and the waterproofing was applied as described above.

The reservoir was designed and erected by Westinghouse, Church, Kerr & Co., of New York, the engineers and constructors of the power plant.

PITTSBURG STORAGE RESERVOIR, KANSAS CITY SO. RY.—This reservoir, 85 feet in diameter, which serves as a storage supply for the Kansas City Southern Railway shops at Pittsburg, Kan., is shown by the

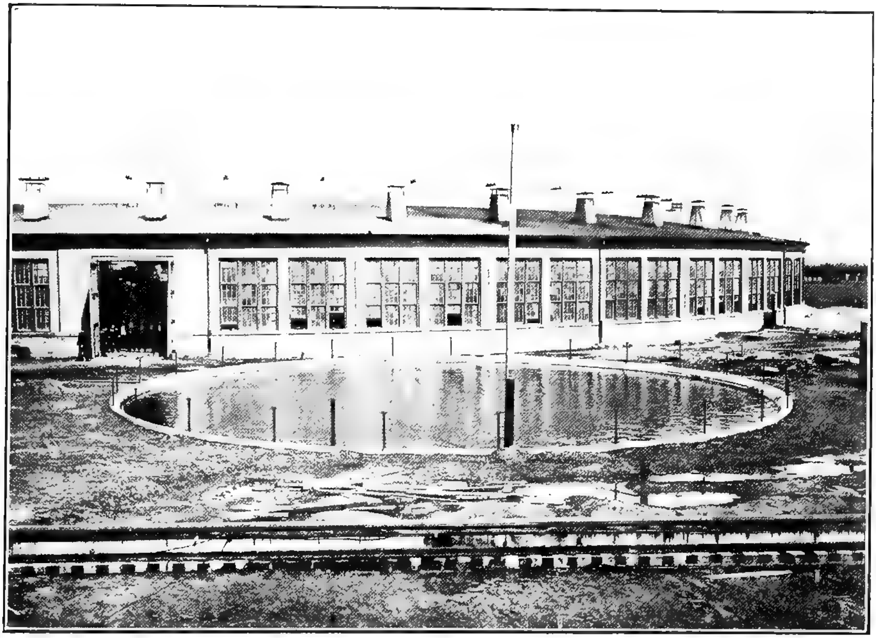


FIG. 121.—PITTSBURG STORAGE RESERVOIR, K. C. S. RY.

photograph in Fig. 121. The reservoir rests on a puddle clay bottom, on which a 6-inch cinder fill is placed, and has a concrete wall 4 inches thick mixed in the proportions of one part Atlas Portland Cement to 2 parts sand to 4 parts broken stone, with a ½-inch 1:1 mortar finish. The total cost of the reservoir, which included 1,500 yards of excavation in addition to 66 cubic yards of 1:2:4 concrete, was $736. The Arnold Company of Chicago were the engineers in charge of the design and construction.

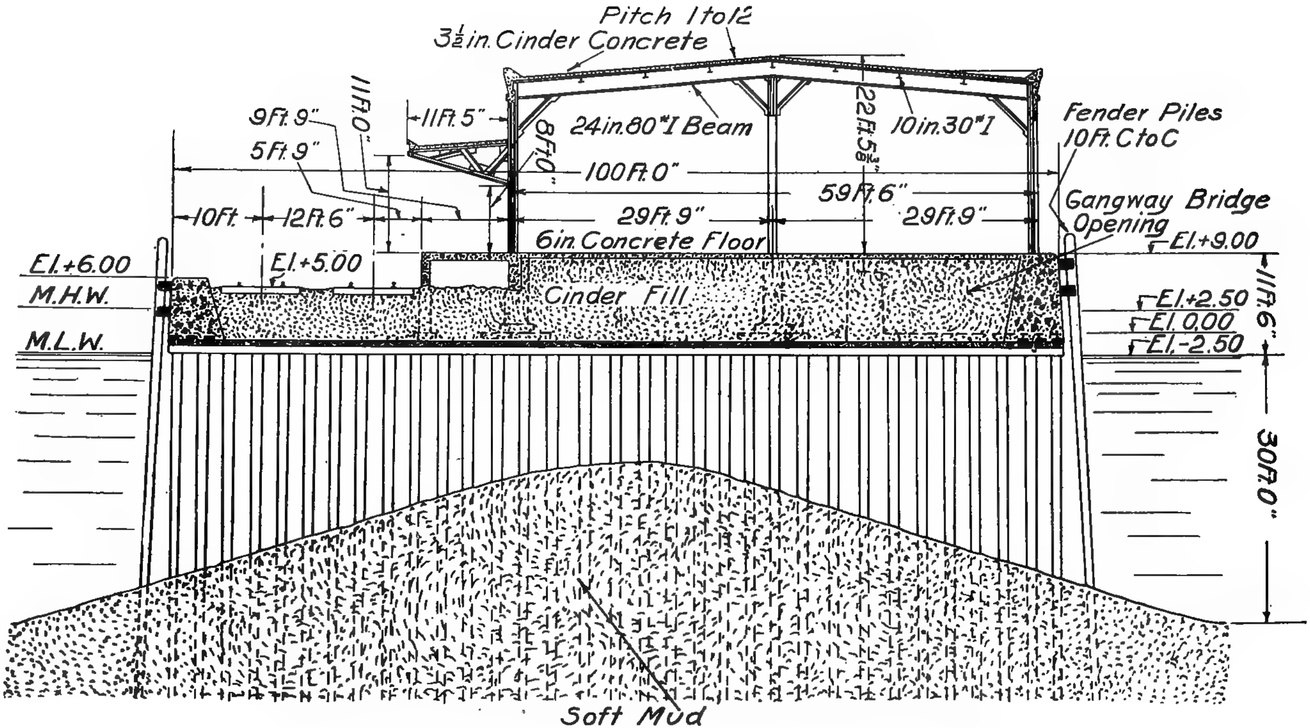


FIG. 122.—CROSS SECTION, HOBOKEN PIER NO. 7, D., L. & W. R. R.

CHAPTER XIII.

DOCKS.

Inasmuch as practically every railroad system in the country owns valuable water front the question of dock construction is a most important one. The recent terrible fires with their attendant devastation along the water fronts of Hoboken and of Boston have demonstrated only too clearly the absolute necessity of positive fire protection in structures of this nature. The new piers which the Delaware, Lackawanna and Western Railroad have designed to replace those burned down in the Hoboken fire of 1904 are to be built entirely of concrete construction from the cut-off of the piles. This type of pier, which is described below, is proof against fire and decay and should be practically free from maintenance.

In the tropics where the waters are infested with limnoria and teredos which destroy a wooden pile in a few years and where the very atmosphere itself eats away unprotected wooden and steel structures reinforced concrete is especially adapted to the construction of wharves and warehouses. Practically all the docks of any magnitude now being constructed in South and Central America and the Philippines are designed as entire concrete structures.

The Almirante wharf of the Changuinola Railroad at Bocas del Toro, Panama, described on page 163, is an interesting example of this type of construction.

HOBOKEN PIER, NO. 7, D., L. & W. R. R.—This pier, which is the first of a series to be built on the same general scheme along a railway yard ship canal, is 100 feet wide and 600 feet long.

As will be seen from the transverse section of the pier, shown in Fig. 122, the construction in general consists of a 6-inch concrete floor carried on a cinder fill retained between concrete face walls and supported on a solid timber of grillage carried on piles cut off at low water level.

These piles, which are from 85 to 95 feet in length, are driven 3 feet apart in transverse rows 5 feet apart. Each pile is proportioned for a maximum load of 12 tons. At mean low water they are capped with continuous, 12 by 12-inch transverse timbers, drift bolted to them. Spiked to these caps are longitudinal 6 by 12-inch planks laid close to form the deck. On either side

of the pier the outer planks alternate with three 12 by 12-inch longitudinal timbers which project above the top of the deck and form ribs to prevent the concrete side walls from slipping or transverse displacement.

The steel shed and platform are carried on concrete piers and longitudinal walls which are built about 11 feet high to the level of the pier floor. The

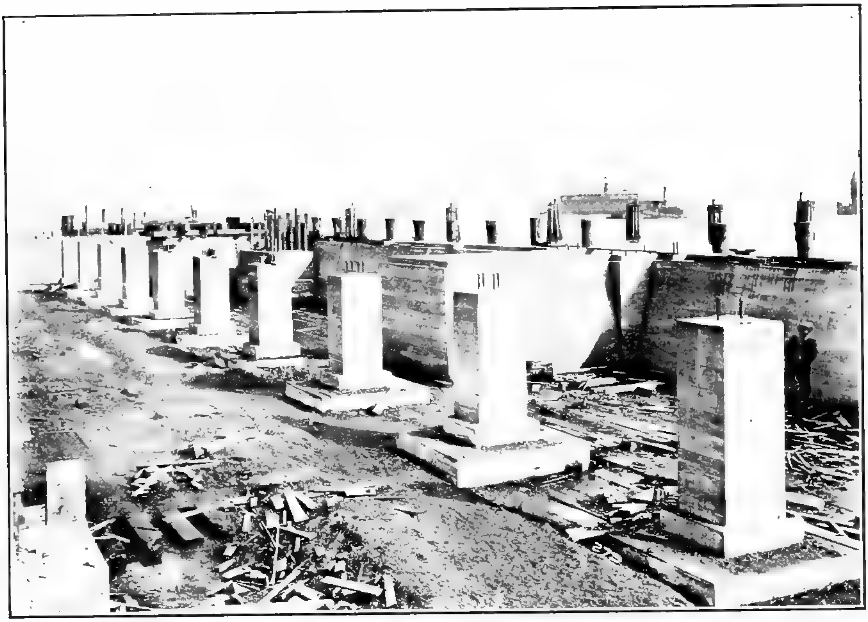


FIG. 123.—HOBOKEN PIER DURING CONSTRUCTION.

photograph in Fig. 123 shows one side wall and one row of intermediate piers during construction.

The space between the side walls is filled with rolled cinders about 9½ feet deep under the shed and 6 feet deep outside where the railroad tracks are laid directly on it.

The pier shed shown in elevation by the photograph in Fig. 124, and in section by the drawings in Fig. 122, is 59½ feet wide and 594 feet long, and consists of a 6-inch concrete floor without surface finish laid directly on the cinder fill with a superstructure of steel framework carrying reinforced concrete walls and roof.

In connection with the side walls, the provision made to allow for the future adjustment of the walls presents an interesting and important feature in construction of this type where settlement of foundation is liable to occur.

The foot of the wall, which is 6 inches thick, is built in a slot in the concrete floor 6 inches deep and 7 inches wide. Two thicknesses of tarred paper separate the wall from the floor thus preventing the possibility of adhesion between the two concrete surfaces, so that the wall, although having a clearance of ½-inch on each side of the slot, is held securely against transverse displacement and forms a closed point at the bottom, the upper edges of the ½-inch crack being caulked with oakum and pointed with cement mortar.

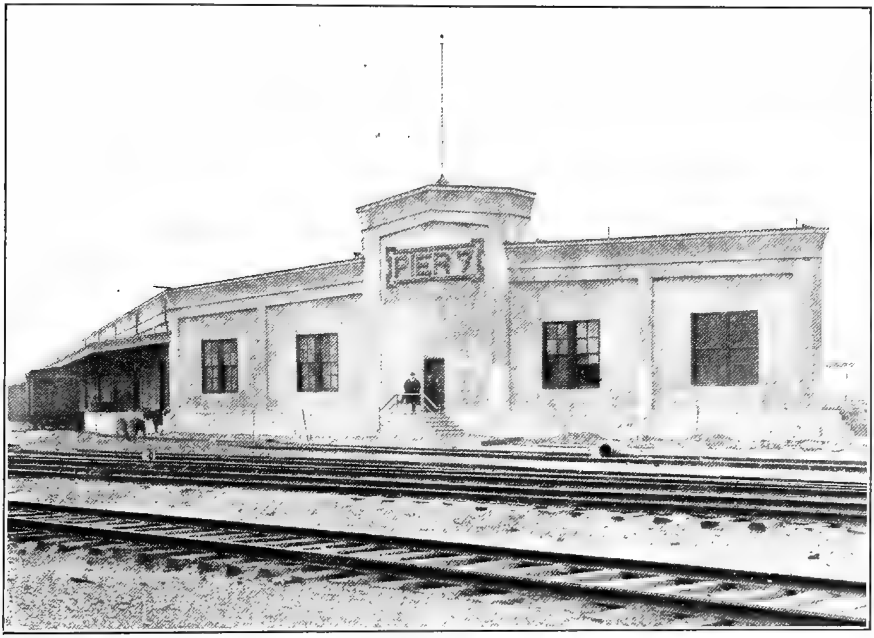


FIG. 124. -PIER SHED, HOBOKEN PIER, D., L. & W. R. R.

If settlement occurs, the wall and the steel superstructure will be jacked up to level the roof and the openings on each side of the slot in the floor will be recaulked and repointed thus restoring the ordinary appearance of the wall.

The shed is divided approximately into equal parts by a transverse reinforced concrete fire wall 12 inches thick.

The pier and shed were designed by the engineering department of the Delaware, Lackawanna and Western Railroad, Mr. Lincoln Bush, Chief Engineer, and Mr. G. T. Hand, assistant engineer in charge of design, and the general contractor was Mr. Henry Steers, of New York City.

ALMIRANTE WHARF, BOCAS DEL TORO, PANAMA.—This wharf which is at the terminus of the Changuinola Railroad, Almirante, Bocas del

Toro, Panama, is of special interest owing to the fact that it is of reinforced concrete throughout and that in its construction the problem of pile protection in the tropics has been successfully solved.

It is approximately 700 feet long and 54 feet wide and is connnected with the mainland by a creosoted timber trestle approach about 800 feet in length. The photograph in Fig. 125 shows one-half of the shore side of the wharf.

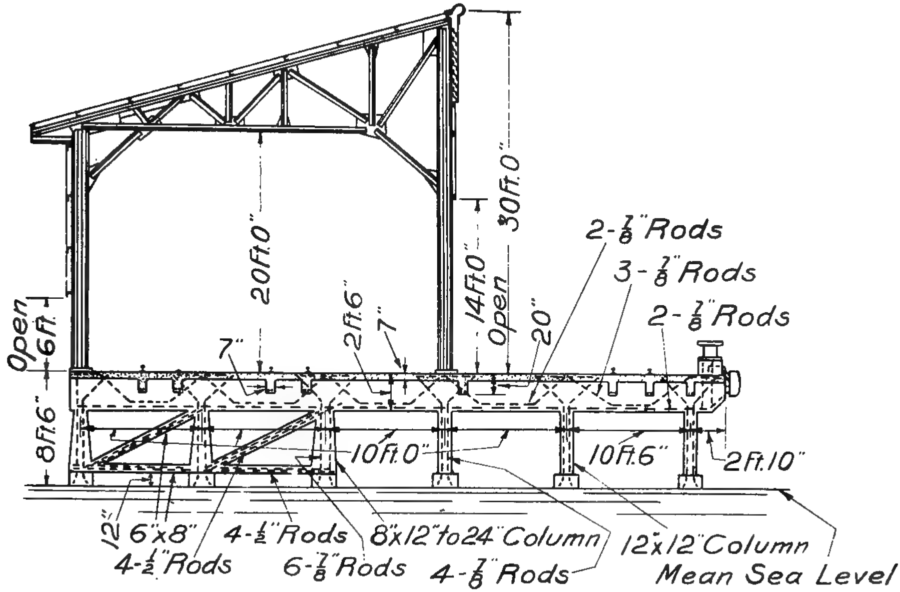
FIG. 125.—ALMIRANTE WHARF, BOCAS DEL TORO, PANAMA.

As the purpose of the wharf is the loading of bananas onto the outgoing, and the temporary storage of general merchandise received from the incoming, steamers, the front of the wharf for a distance of 23 feet is open to allow the free use of automatic loading machines, while the remainder is covered with a steel storage shed, open 6 feet from the bottom in the rear and 14 feet in the front. The bananas are carried to the loading machines by a 3-foot gauge track in front connected by cross-overs to two similar tracks running the length of the storage shed.

As will be seen from the cross section in Fig. 126, which shows the essential details of design and construction, the wharf consists of a series of reinforced concrete columns supporting a system of main girders and cross beams which in turn carry a 7-inch floor slab. The columns rest on wooden piles spaced 10 feet on centers, protected by a four-inch covering of concrete.

This method of protecting the wooden piles from the attacks of teredos

consisted in driving a 2-inch concrete shell—20 inches in diameter at the top and 16 inches at the bottom reinforced its full length with 4-inch by 12-inch wire cloth over the wooden pile and into the harbor bottom two feet. The shell was then sealed at the bottom with concrete, the water pumped out and the intermediate space between the shell and the pile filled with concrete to the level of the top of the shell which was about 2 feet above the top of the pile and 1 foot above high water. The shells were made in lengths



TRANSVERSE SECTION

FIG. 126.—CROSS SECTION, ALMIRANTE WHARF.

varying from 32 feet to 12 feet according to the depth of water and were composed of concrete mixed in the proportions of 1 part Portland cement to 2 parts of crusher dust to 3 parts of ½-inch broken stone, and the filling consisted of concrete mixed in the proportions of 1:2:4.

In constructing the columns, girders and beams, a mixture of 1 of cement to 2 of sand to 2 of crusher dust to 3 of 1-inch broken stone was used and for the floor slabs a mixture of 1:2:1:3 of the same materials.

The reinforcing rods for the columns were embedded four feet in the filling between the shells and the piles and were carried up through the main girders and into the floor slab, thus securely tieing together the entire structure. For the columns, main girders and railroad beams, ⅞-inch round rods were used for reinforcing, and for the floor slab, ½-inch round rods.

Fig. 127 shows in detail the ship buffer, which consists of two 8 by 12-inch creosoted timbers protected by 2 by 10-inch wearing strips every 3 feet 4 inches with a railroad car spring of 19,000 pounds resistance, resting in a cast steel socket embedded in the concrete at each bent to take the shock.

Every 50 feet, hollow steel mooring bits were placed on, and bolted to, concrete pedestals and were then filled with concrete as shown by the detail in Fig. 127.

With the exception of general foremen, native and Jamaican labor was used throughout, both for building the forms, placing the concrete and erecting the steel shed.

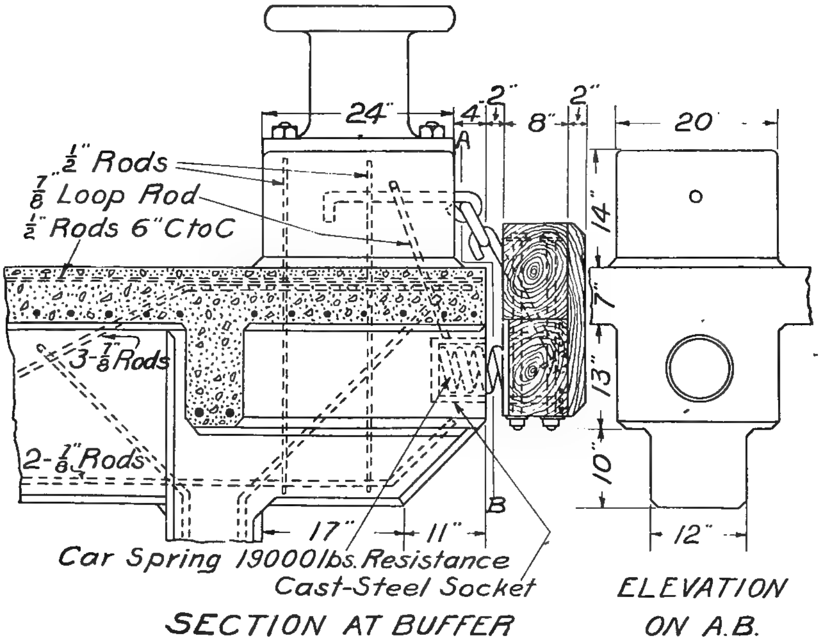


FIG. 127.—DETAIL OF SHIP BUFFER, ALMIRANTE WHARF.

The mechanical equipment consisted of a stone crusher, a 3/4-yard rotary mixer with hoist, a floating pile driver with a No. 3, 4,500-pound steam pile hammer, 6 charging carts, an improvised machine for bending the rods cold, and a number of narrow gauge cars on which the shells were made.

The wharf was designed by Mr. T. Howard Barnes with Mr. J. R. Worcester as consulting engineer, and was constructed under his supervision in the fall of 1907 and the winter of 1908, with Mr. Chester S. Allen as resident engineer and Mr. Robert V. O'Brien as superintendent for the United Fruit Company.

CHAPTER XIV.

TUNNELS AND TUNNEL LINING.

One of the most common uses of both plain and reinforced concrete is in the construction of tunnels and subways. The term tunnel as generally understood by railroad engineers is applied to construction under cover, in which the tunnel bore is advanced by drifting, the surface of the ground above the work not being disturbed. The term subways is applied to open cut construc-

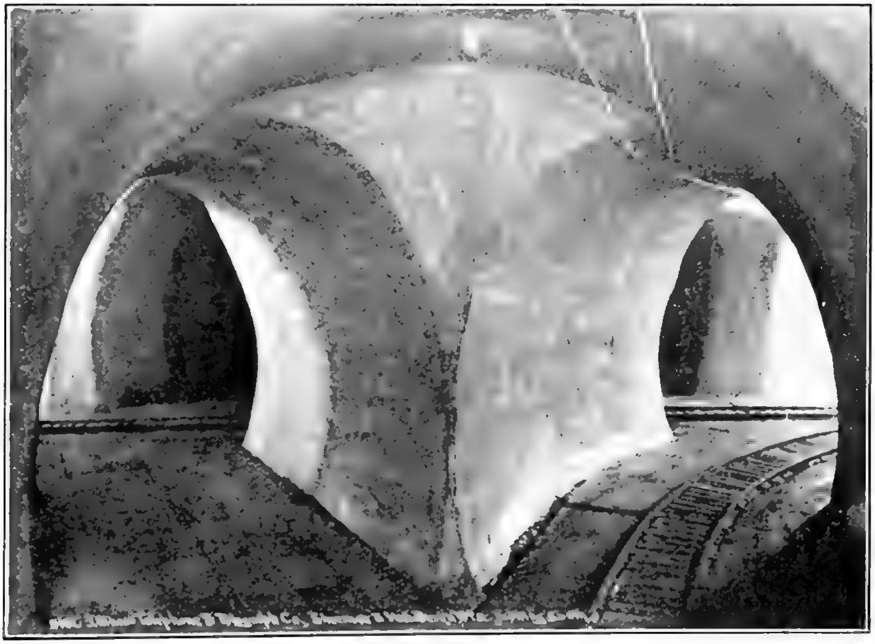


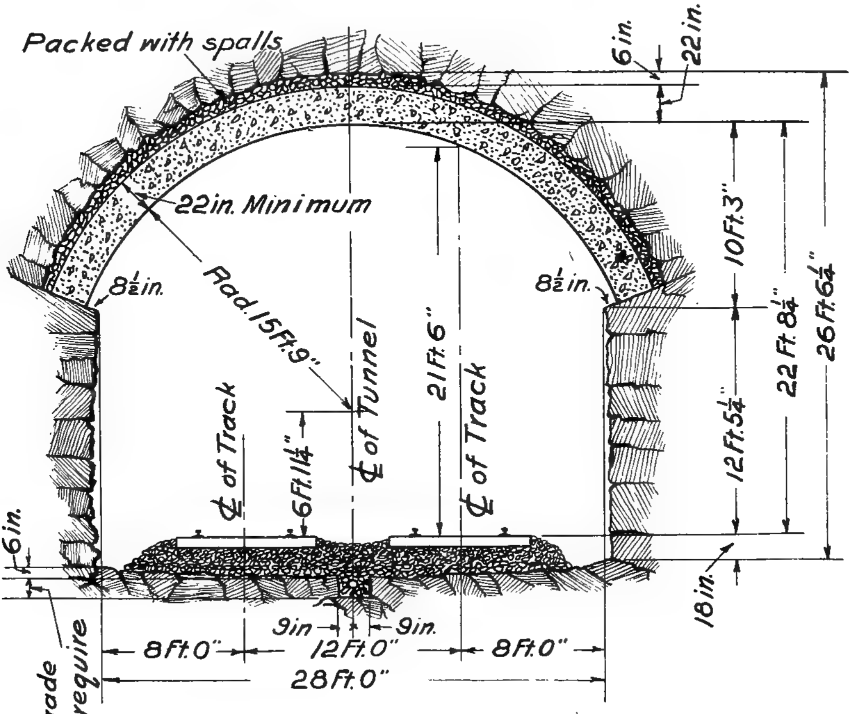
FIG. 128. -ILLINOIS TELEPHONE AND TELEGRAPH TUNNEL, CHICAGO, ILL.

tion. A tunnel for heavy and fast railroad traffic should be built with the entire lining, and for still greater economy with the roadbed of concrete. The old Bergen Hill tunnel on the Lackawanna Railroad is lined with brick for a portion of its length, yet fourteen men are at work every night in the year inspecting the lining and repairing the track. This expensive and dangerous maintenance work, which costs annually approximately $6,000, is prac-

tically eliminated in the new tunnel described on page 173, which is built with the entire lining and roadbed of concrete.

The standard tunnel sections of the New York Central and Hudson River Railroad described below and illustrated by the drawings in Figs. 129, 130, 131, 132, 133, show the methods of construction employed in building tunnels through the different kinds of material encountered in this class of work.

At the end of the book are shown photographs of a number of representative types of tunnels constructed by various railroads throughout the country.

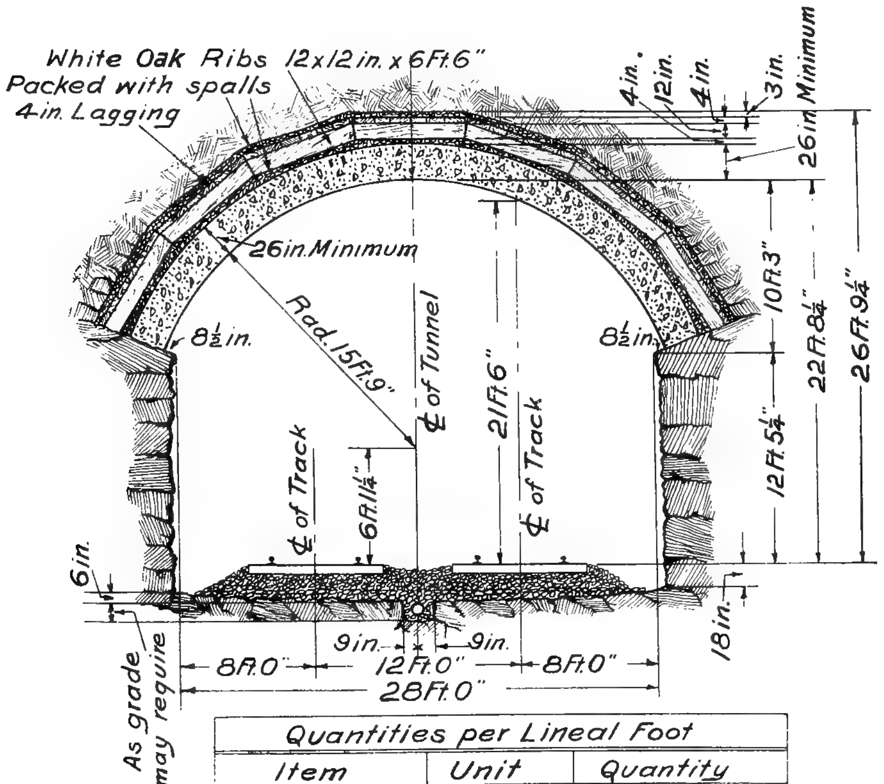


Quantities per Lineal Foot		
Item	Unit	Quantity
Excavation	Cu. Yds.	26.493
Roof Masonry	Cu. Yds.	2.232

FIG. 129.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE B, SOLID ROCK, FIRM SIDES AND ROOF, DANGER FUTURE FALLS.

STANDARD TUNNEL SECTIONS, N. Y. C. & H. R. R. R.—Type B, Fig. 129 shows a cross section of the standard tunnel designed to meet the condition of solid rock with firm sides and roof but with danger from future

falls. The lining for the arch is 22 inches thick and is composed of plain concrete mixed in the proportions of 1 part Portland cement to 2 parts of sand to 4 parts of broken stone. While the distance given between the tracks is 12 feet, this may be increased to 13 feet without changing the width of the tunnel. Vitrified pipe, whose size depends upon the length and amount of water to be carried off, is laid in the drain with open joints.



Quantities per Lineal Foot

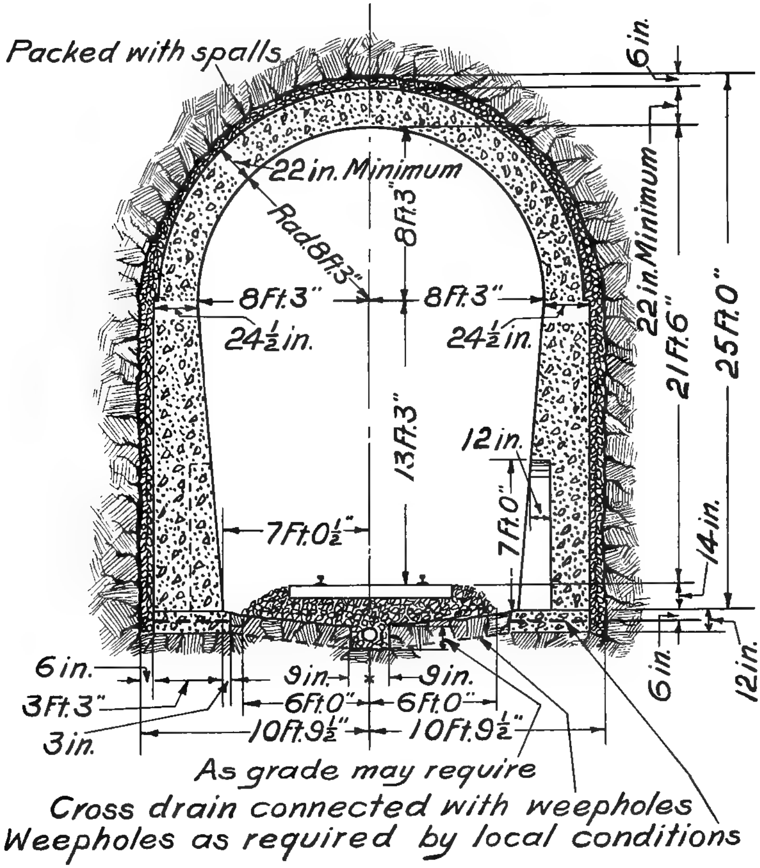
Item	Unit	Quantity
Excavation	Cu. Yds.	29.493
Roof Masonry	Cu. Yds.	3.233
*Timbering	Ft. B.M.	306.

* Based on Rib spacing of 5 Ft. C to C

FIG. 130.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE C, SOLID ROCK, YIELDING ROOF, FIRM SIDES.

Type C, Fig. 130, shows a cross section of the tunnel where the lining is through solid rock and the tunnel is designed with firm sides and yielding roof. The concrete lining for the arch is 22 inches thick and is mixed in the proportions of 1:2:4. The 12 by 12-inch oak ribs carrying the 4 by 8-inch

lagging are spaced 5 feet center to center. The quantities per lineal foot are given in tabulated form in Fig. 130.

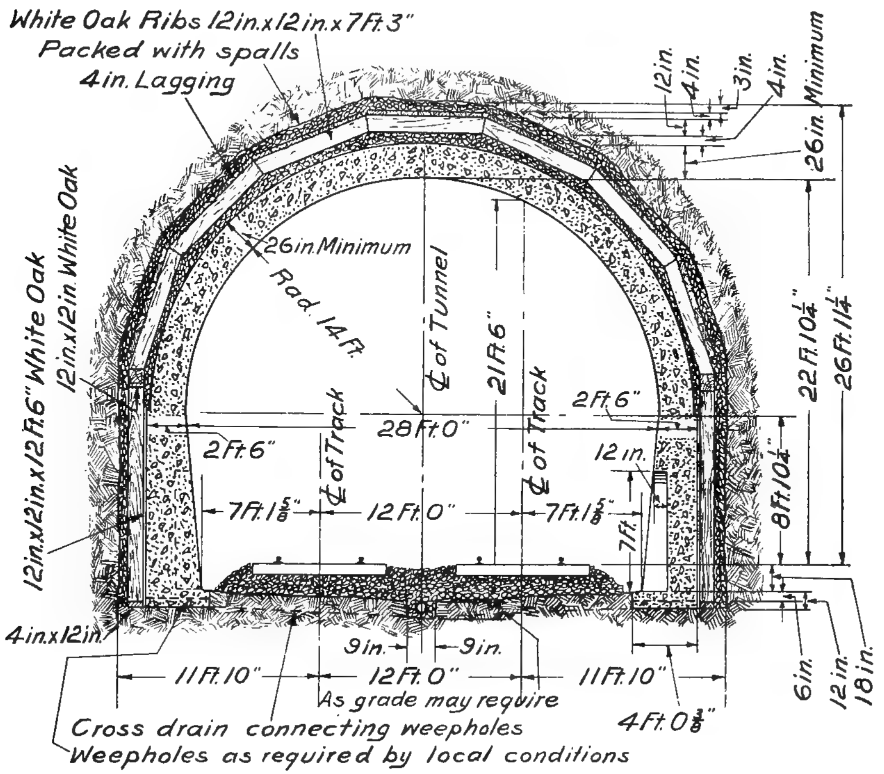


Quantities per lineal Foot		
Item	Unit	Quantity
Excavation	Cu. Yds.	18.537
Arch Masonry	Cu. Yds.	1.955
Side Wall	Cu. Yds.	3.085

FIG. 131.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE D, FIRM BUT NOT SELF-SUSTAINING MATERIAL

Type D, Fig. 131, is a cross section of a tunnel through firm but not self-sustaining material. The lining is composed of 1:3:6 concrete. Every 200 feet, staggered on each side of the tunnel, are placed refuge niches as shown

in Fig. 131. These niches are 7 feet high and 3 feet wide, with semicircular tops. All exposed corners and edges are rounded to a 1-inch radius. While the section given in Fig. 131 is for a single track the same methods of construction and general clearance distances apply to double track construction.



Quantities per Lineal Foot		
Item	Unit	Quantity
Excavation	Cu. Yds.	33.568
Arch Masonry	" "	3.803
Side Wall "	" "	2.547
*Timbering	Ft. B.M.	425.

*Based on Rib Spacing of 5Ft. C to C

FIG. 132.—STANDARD TUNNEL, N. Y. C. & H. R. R. R., TYPE E, YIELDING MATERIAL.

Type E, Fig. 132, shows a cross section designed to meet the condition of yielding material. The concrete lining is mixed in the proportion of 1:2:4 and is provided with refuge niches similar to those described in Type D.

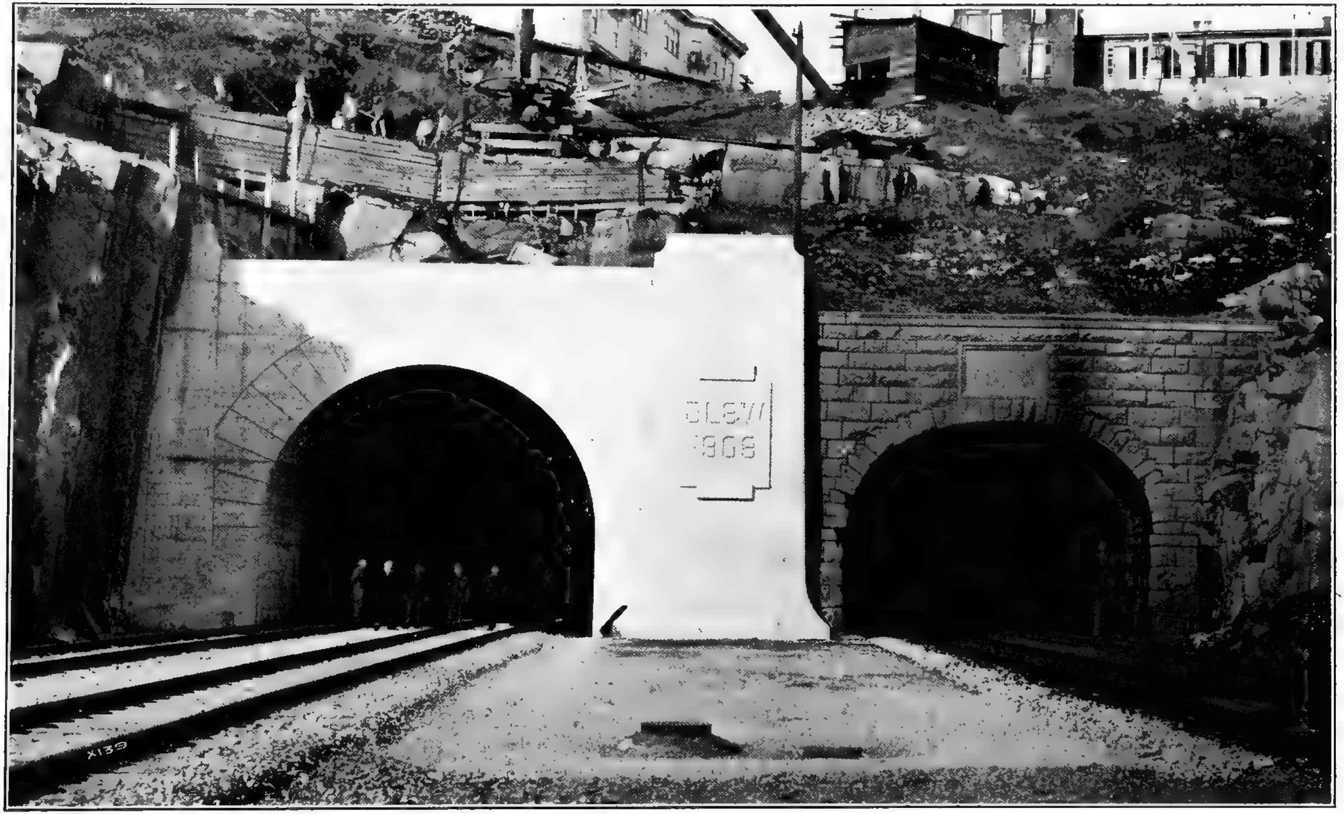


FIG. 133.—ENTRANCE TO OLD AND NEW BERGEN HILL TUNNELS.

The 12 by 12-inch white oak ribs carrying the lagging are spaced 5 feet on centers. The quantities per lineal foot are tabulated in Fig. 132.

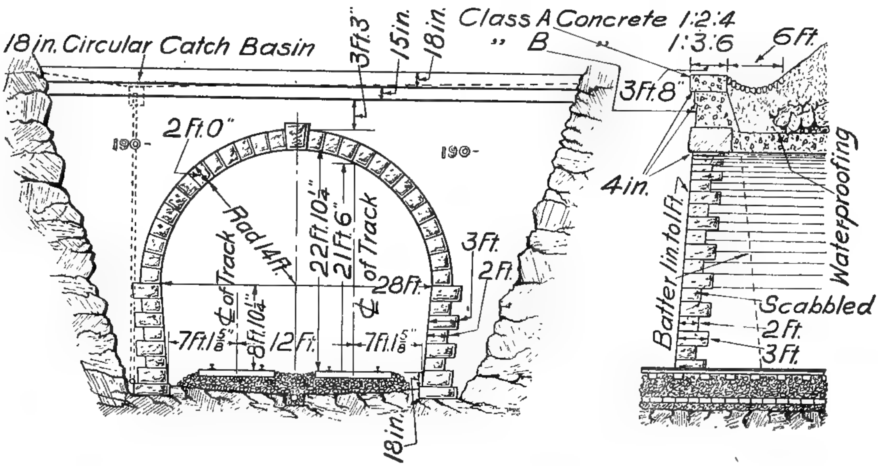


FIG. 134.—STANDARD DOUBLE-TRACK TUNNEL FACADE, N. Y. C. & H. R. R. R.

STANDARD TUNNEL FACADE.—The standard facade for the different types of tunnels described above is shown in Fig. 134. With the exception of the arch ring, which is of scabbled granite, the entire facade is of concrete mixed in the proportions of 1:3:6 for the main body and of 1:2:4 for the coping.

NEW BERGEN HILL TUNNEL, D., L. & W. R. R.—As will be seen from the cross section in Fig. 135, this tunnel is 30 feet wide in the clear, 23 feet 5 inches high from the base of the rail to the crown of the roof arch, and has a concrete lining of a minimum thickness of two feet. The length of the tunnel is 4,280 feet and at two points located at about one-third the length of the tunnel from each portal it is connected to the old tunnel, which is immediately alongside the new one, by an open cut extending across the four tracks, 100 feet long and 80 feet wide.

At about the center of each of the sections, into which these open cuts divide the tunnel, shafts 10 feet long and 30 feet wide were sunk to the new tunnel. These shafts and open cuts were used to good advantage in moving the waste material from the headings and they also greatly facilitated the work of placing the concrete lining.

The concrete, which was mixed in the proportions of 1:2½:5, was placed so as not to require tamping and was carefully spaded from the face of the forms which were lined with No. 20 gauge sheet steel well greased. This resulted in giving the exposed surface of the concrete a smooth metallic appearance which required no further finishing.

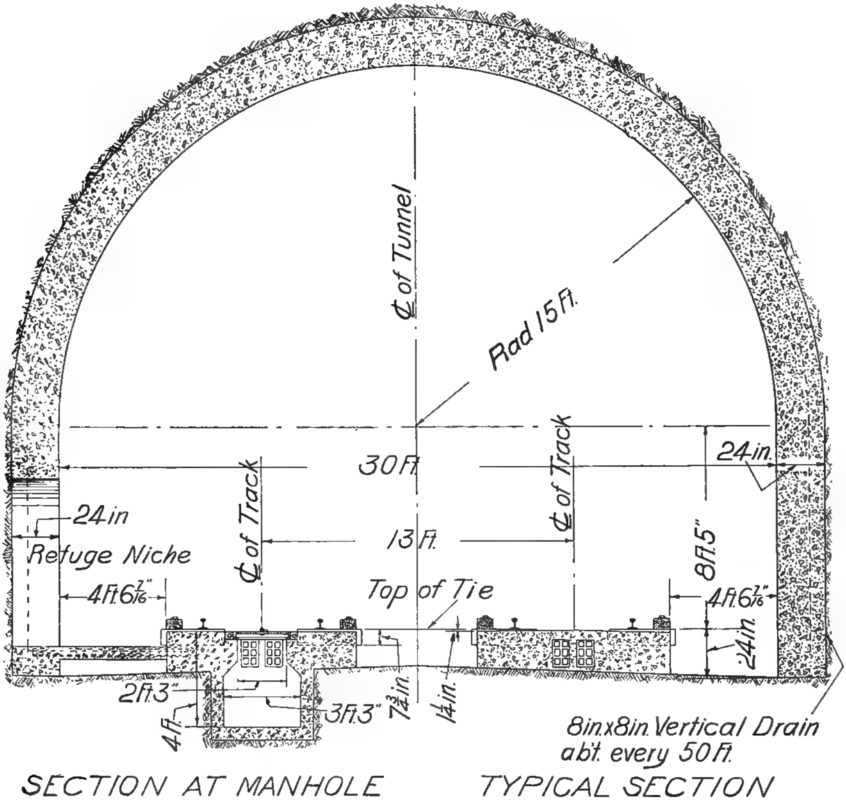


FIG. 135.—CROSS SECTION, NEW BERGEN HILL TUNNEL.

The development of the portals is shown by the photograph in Fig. 133, and the roadbed construction is described in detail on page 178, Chapter XV.

The tunnel was designed and built, during years 1906 to 1908, under the direction of the engineering department of the Delaware, Lackawanna and Western Railroad, Mr. Lincoln Bush, chief engineer, and the lining was put in by Arthur McMullen & Company, contractors, New York.

CHAPTER XV.

CONCRETE TIES AND ROADBEDS.

TIES.

One of the most serious and perplexing questions which confronts the railroad engineer of to-day is the tie problem. As an evidence of this, during the year 1907 the railroads of the United States used approximately 118,000,000 ties, a very large percentage of which were renewals.

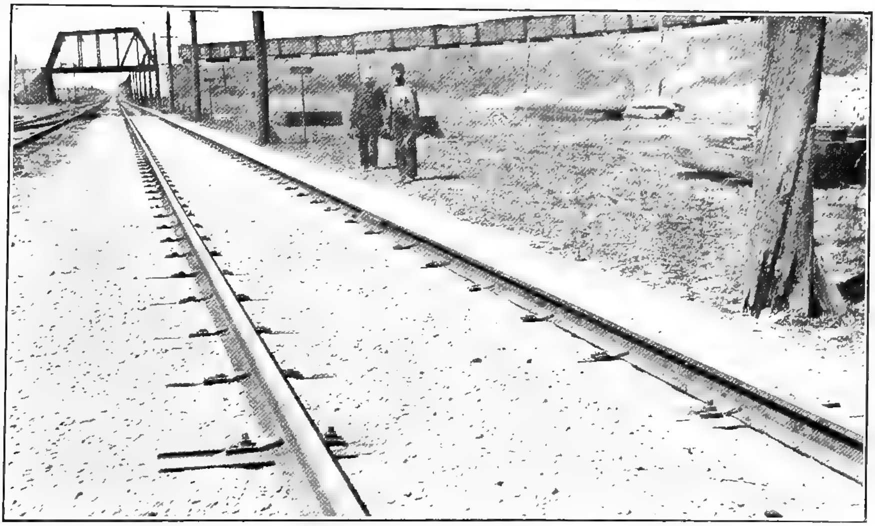


FIG. 136.—CONCRETE TIES ON INTERNATIONAL RY., BUFFALO.

This vast inroad upon the limited and rapidly decreasing supply of timber has caused wooden ties to become poor in quality and high in price, with a result that railroad engineers realize the necessity of procuring a substitute and have been experimenting with concrete ties of various designs for the past few years. While none of these ties have been tested long enough under heavy and high speed traffic to warrant selecting any one as a proper substitute for the wooden ties under all conditions, the success of some of the ties

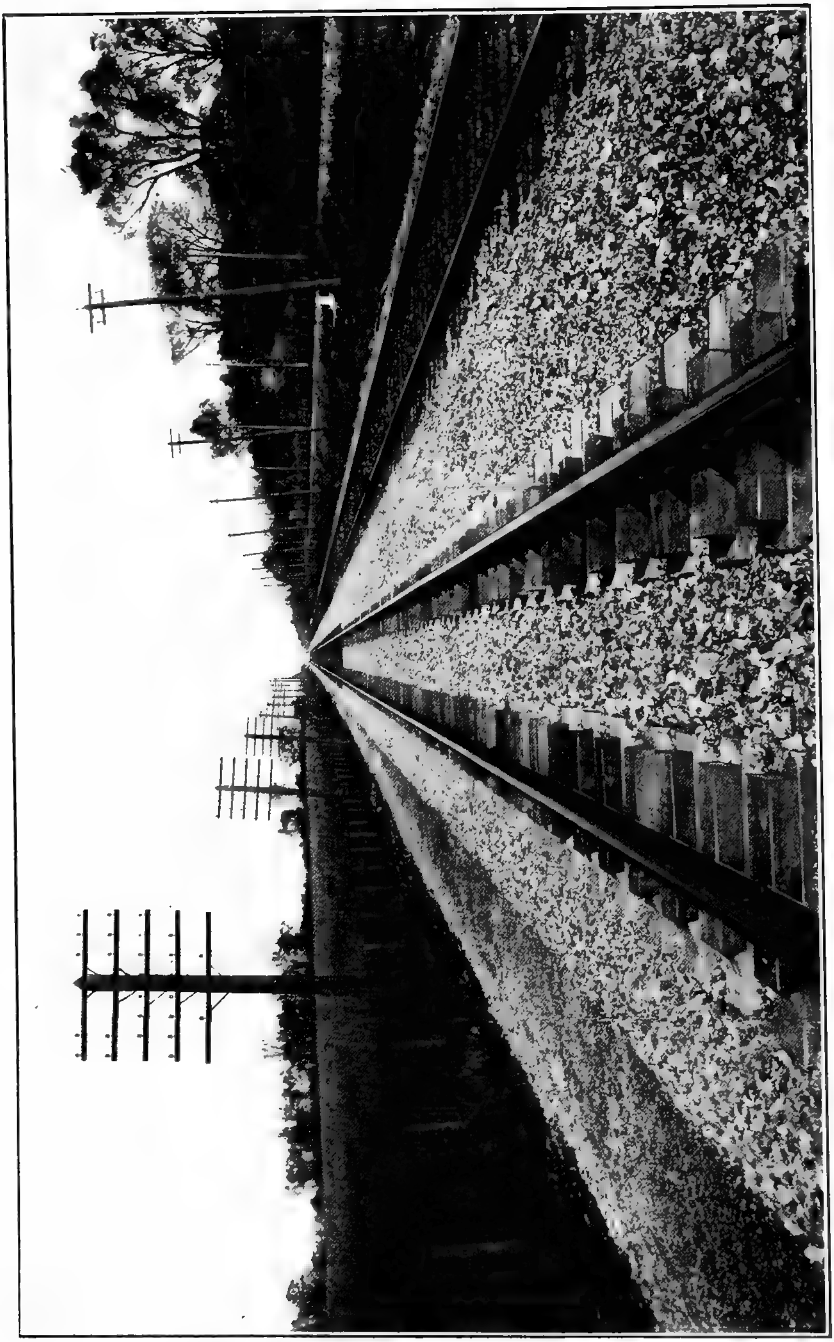


FIG. 137.—CONCRETE TIES ON CHICAGO AND ALTON R. R.

tested thus far has been great enough to convince railroad engineers who have given the most study to the subject that a properly reinforced concrete tie with proper fastenings is a practical and economical tie, at least for tracks where the speed is low and where conditions are adverse to the life of wood or metal. There is no question but what concrete ties are entirely suitable and economical for use in yards and sidings and that there is an enormous place for their introduction into this field alone.

Concrete ties possess certain natural advantages over either timber or steel inasmuch as dampness, drawn fires and insects have absolutely no effect upon them. In addition, they are practically independent of the steel and timber market, and can be made along the line of the railroad, and, as compared with the chemically treated timber or the steel tie, at a reasonable cost.

Concrete ties have been in successful use in Indo-China, where a very peculiar species of ant destroys wooden ties in a few months, for about ten years. At the present time it is estimated that there are over 1,000,000 of these ties in service. They are of an inverted T-section, the flange of which is laid on the ground, the stem being vertical. The rails are fastened by bolts which are imbedded in an enlargement of the stem where the rails pass. In Italy concrete ties have been tried with such success that the Italian government has recently placed an order with various manufacturers in Italy for 300,000 concrete ties.

In the design of a successful tie there are a number of important functions that seem to be more or less overlooked in many of the ties thus far built.

Cushion blocks, if used, should be removable, and the fastenings be of such a nature that they will neither have a tendency to shake loose nor be inaccessible, and may be renewed if injured.

Inasmuch as automatic block signalling is being extended very rapidly upon practically all of the railroads, it is important that the rails should be insulated, and therefore it is necessary to place sufficient concrete between the metal in contact with the rails and the longitudinal reinforcement.

Many long ties have failed from the fact that they were not designed to act as cantilever beams, thus being unable to withstand the severe shocks coupled with the sinking of the tie under passing loads on center bound track. The difficulty experienced with tie blocks has been in keeping them in longitudinal position and maintaining them so that the vertical deflection of one rail will not greatly exceed that of the other, thereby causing rolling and pounding of the equipment.

Finally, ties should be of sufficient strength to support derailed cars and engines until they are off the ends of the ties and actually into the ditch; otherwise, an ordinary derailment may become a serious wreck.

While the original cost of a solid concrete roadbed is greater than the ordinary cross-tie construction, it is undoubtedly more economical in the end for tunnels and subways; especially so where space is cramped, traffic heavy, and a track cannot be temporarily abandoned, and where with the running

FIG. 138.—EXPERIMENTAL CONCRETE ROADBED, N. Y. C. & H. R. R. R.

rails, guard rails and third rails attached to the long ties—as in the case of electrified lines—it is extremely difficult and very expensive to maintain and tamp up track to surface and make tie renewals.

Also, it can be used to great advantage and economy in rock and earth cuts where there is always a large maintenance expense to keep ditches open and track in good surface.

In addition to the question of ultimate economy, the solid concrete roadbed is especially commendable for tunnel and subway construction from a hygienic standpoint; for in most tunnels and subways ventilation is difficult and the accumulation of grease, dirt and débris, which is readily held by the ballast of the cross-tie track construction, is a serious menace to the health of the passengers. This can be eliminated in the solid concrete construction

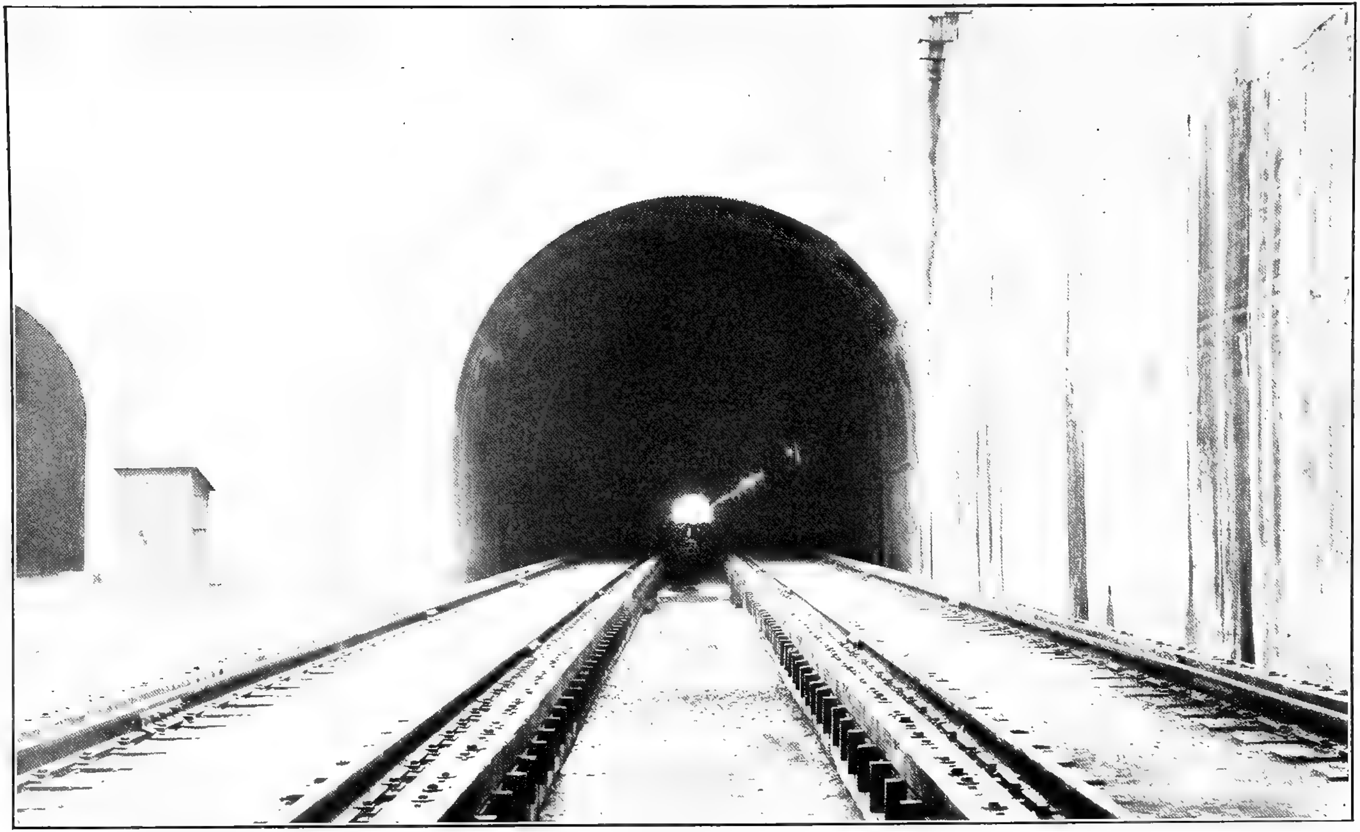


FIG. 139.—VIEW TAKEN AT ONE OF THE TWO OPEN SHAFTS IN THE INTERIOR OF TUNNEL SHOWING FINISHED ROADBED.

as the entire roadbed can be flushed with water and kept in a neat, clean and sanitary condition.

ROADBED CONSTRUCTION OF THE NEW BERGEN HILL TUNNEL, D., L. & W. R. R.—The drawings in Fig. 140 show the essential features

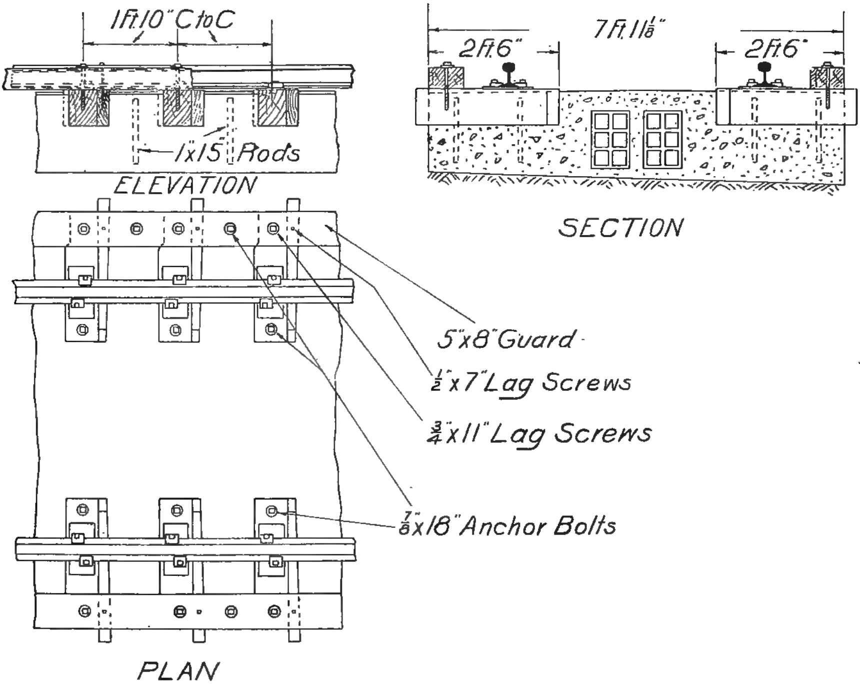


FIG. 140.—CONCRETE ROADBED, NEW BERGEN HILL TUNNEL.

of design and construction, while the photograph in Fig. 139, which is a view taken at one of the two open shafts in the interior of the tunnel, shows the finished roadbed.

This construction consists of a roadbed of concrete laid on the rock bottom of the tunnel with 8 in. by 8 in. creosoted timber tie blocks 2 feet 6 inches long set in the concrete and spaced 1 foot 10 inches apart on centers for supporting the rails. These tie blocks leave a notch at the outer end to form a shoulder, and are set in the concrete when it is built. The concrete fills the space made by the notch in the tie block, and prevents the lateral shifting of the block and railroad rail, which is attached to it by lag screws and wrought iron clips. A tapered creosoted wedge block holds the tie block tight against

the concrete, and can be driven in to take up any looseness due to shrinkage or wear. The wedge is held in place by a lag screw extending about 2 inches into it through the guard rail. As will be seen from the drawings, the guard rail is fastened to the tie blocks by lag screws, and is also anchored to the concrete by anchor bolts.

To replace the tie blocks, the lag screws are removed, the wedge withdrawn, the tie block moved forward until the shoulder of the block clears the

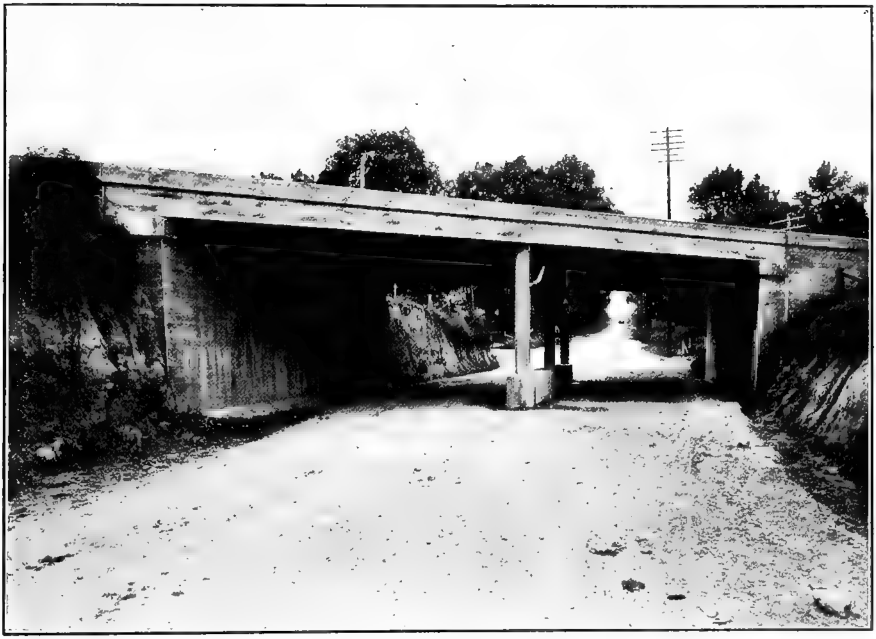


FIG. 141.—BRIDGE WITH CONCRETE FLOOR, ILL. CENTRAL R. R.

shoulder in the concrete, and the tie block is then pulled out laterally without disturbing the adjacent tie blocks or rail fastenings and without raising the rail, thus not interfering with traffic.

One man can replace these tie blocks and wedges, while with the ordinary type of ballast track construction it is necessary for a gang of men to dig out the ballast in order to replace a tie, and it also is necessary to protect traffic while the work is being done.

The proportions used in the track superstructure were one part of cement to 6 parts of Cowe Bay gravel and sand, and in the sub-base the proportions were 1 part of cement to 12 parts of crushed stone and sand for bringing the sub-base up to proper level.

The table on page 183 gives an estimated cost of the ballasted roadbed construction for double track. So far as the amount of tunnel excavations and the cleaning up of muck under the roadbed are concerned, the cost would be the same whether ballasted track or concrete roadbed were used, but with the concrete roadbed the tile drains and trenching for ditches for the drains are eliminated. The estimated total cost, including the conduits, tile drains, creosoted ties, etc., as detailed, for the ballasted double track, for a length of 4,280 feet amounts to $62,568.87, which would be at the rate of $14.62 per lineal foot of double track. If the conduit construction is eliminated from consideration, the total cost amounts to $43,429.87, or $10.15 per lineal foot of double track.

On page 184 is given a detailed statement of the actual cost of the concrete roadbed construction, which does not include any estimate for the concrete sub-base under the finished track superstructure. The statement in detail shows the actual cost for 4,280 lineal feet of double track as taken from the company's invoices and records. It will be noted that this statement includes the two lines of 12-hole conduits.

The railroad furnished sand, stone and cement for the concrete work, and the price of $6.25 per cubic yard given in the detailed statement for concrete roadbed includes the contractor's price, plus the cost of material. The contract provided that the contractor would lay the conduits, the railroad company to furnish the material and the contractor to receive the same price per cubic yard for the work as he received for the balance of the concrete work, for tunnel lining, namely $3.50 per cubic yard. This price of $3.50 per cubic yard included everything excepting sand, stone and cement. The company assembled the tie blocks and rail and the cost of these items is included in the detailed statement. The cost thus figures $14.26 per lineal foot of double track. Eliminating the conduit construction from consideration, the cost per foot of double track for concrete roadbed amounts to $13.18 per lineal foot of double track as against $10.15 per lineal foot of ballasted double track. Had the conduits been eliminated from the concrete roadbed construction, the superstructure could have been made about 4 inches less in height, which quantity would have practically made up for the area of concrete occupied by the conduits.

So far as the maintenance cost is concerned, the concrete roadbed construction has resolved itself into a question of simply track inspection, and one inspector during the night and one during the day is all that is necessary. When a tie block must be renewed, it can be done without disturbing in any way the rail fastenings to the tie blocks on either side of the one to be renewed, and no removal of rail will be necessary. One man can readily replace a tie block 8 inches by 8 inches by 2 feet 6 inches, and no interference whatever would occur with traffic during such renewal, as an inch board could be placed underneath the rail on top of the concrete, either side of the block to be renewed, for temporary support.

Still another detailed statement is given below showing the actual cost to the company per annum to maintain ballasted track in the present old Bergen Hill Tunnel, which is of the same length as the new tunnel, the traffic through it being very heavy. Capitalizing the investment for ballasted track construction and for concrete roadbed construction (includng conduits) at 4 per cent, and taking into consideration the difference in cost of maintaining, shows from these figures that the saving per annum in cost per mile of double track (with conduits) amounts to $7,107.32, and without conduits the saving per annum per mile of double track concrete roadbed would be $6,389.42.

ESTIMATED COST OF BALLASTED TRACK CONSTRUCTION FOR DOUBLE TRACK THROUGH NEW BERGEN HILL TUNNEL OF THE DELAWARE, LACKAWANNA & WESTERN R. R. AT JERSEY CITY, N. J.

Length of tunnel—4,280 feet.

232	Gross tons 91-lb. special open hearth rail,	@	$34.00	$7,888.00
520	Pairs of angle bars	@	1.07	556.40
3120	Spliced bolts	@	.03 1/3	104.00
3120	Nut locks	@	.009	28.08
8835	Tie plates, 6″ × ½″ × 9″	@	.131	1,157.38
520	Joint tie plates, 6″ × ½″ × 11″	@	.171	88.92
18710	Spikes	@	.01¾	327.40
4677	Creosoted Y. P. ties, 7″ × 9″ × 8 ft. 6″	@	2.10	9,821.70
6737	Cu. yd. stone ballast, delivered	@	1.00	6,737.00
17976	Lin. ft. of vitrified 6-hole conduits, 5% allowed for breakage	@	.225	4,044.60
5720	Yd. drilling for wrapping conduit joints	@	.095	543.40
2035	Cu. yd. rock excavation for tile drains	@	7.00	14,245.00
8988	Lin. ft. 8″drain tile, 5% added for breakage	@	.085	763.97
2000	Cu. yd. of extra concrete for conduits	@	6.25	12,500.00
8560	Lin. ft. single track laying and surfacing	@	.20	1,712.00
586	Cu. yd. concrete voids occupied by conduit	@	3.50	2,051.00
				$62,568.87

$62,568.87 4280 = $14.62 per foot of double track.
If conduits are eliminated from consideration, cost would be $43,429.87.
$43,429.87 ÷ 4280 = $10.15 per foot of double track.

DETAILS OF ACTUAL COST OF CONCRETE ROADBED CONSTRUCTION FOR DOUBLE TRACK THROUGH NEW BERGEN HILL TUNNEL OF THE DELAWARE, LACKAWANNA AND WESTERN RAILROAD AT JERSEY CITY, N. J.

Estimate includes electric wire conduits. Length of tunnel, 4280 feet.

232	Gross tons 91-lb. special open hearth rail,	$34.00	$7,888.00
520	Pairs of angle bars,	1.07	556.40
3120	Splice bolts	.03 1/3	104.00
3120	Nut locks,	.009	28.08
8835	Tie plates, 6″ × ½″ × 9″,	.131	1,157.38
520	Joint tie plates, 6″ × ½″ × 11″,	.171	88.92
17976	Lin. ft. vitrified 6-hole conduit, 5% allowed for breakage,	.225	4,044.60
5720	Yd. drilling for wrapping conduit joints,	.095	543.40
9360	Creosoted yellow pine tie blocks, 8″ × 8″ × 2 ft. 6,″	45.00	5,616.00
9360	Creosoted yellow pine wedges, 2¼″ × 8″ × 2 ft. 6″,	45.00	1,579.50
17680	Intermediate rail clips,	.039	689.52
18720	Pieces round iron 1″ × 15″ for reinforcement,	.06 1/3	1,185.60
1040	Joint rail clips,	.051	53.04
18720	Lag screwspike, ⅞″ × 7½″,	.046	861.12
9360	Lag screws for guard rail, ¾″ × 11″,	.034	318.24
9360	Washers for guard rail, ⅜″ × 3″,	.03	280.80
9360	Wedge lag screws, ½″ × 7″,	.013	121.68
18555	Lin. ft. of Y. P. creosoted guard rail, 5″ × 8″,	45.00	2,783.25
4680	Guard rail anchor bolts, ⅞″ × 18″,	.08 2/3	405.60
4680	Guard rail washers, ⅜″ × 3″,	.03	140.40
4680	Anchor nuts, 2¼″ sq. × 1¼″ thick,	.08	374.40
4680	Paraffine tubes for anchor bolts,	.005	23.40
3754.4	Cu. yd. concrete,	6.25	23,465.00
1019.2	Cu. yd. concrete voids occupied by tie blocks, wedges and conduits,	3.50	3,567.20
	Labor and engineering for assembling and fastening complete, the tie blocks, wedges, guard rail, rail, rail joints, screws, spikes, etc., 8560 lin ft.,	.60	5,136.00
			$61,011.53

$61,011.53 — 4280 = $14.26 per linear foot of double track with conduits and wrapping.

$56,423.53, total cost, exclusive of conduits.

$56,423.53 — 4280 = $13.18 per linear foot of double track.

COST PER ANNUM BALLASTED TRACK (With Conduits)

$62,568.87, @ 4%	$2,502.75
Track maintenance, $565.00 per mo. × 12	6,780.00
Length of 4280 ft.	$9,282.75
$\$9{,}282.75 \times \frac{5280}{4280}$	$11,451.57 per mile

COST PER ANNUM BALLASTED TRACK (Without conduits)

$43,429.87, @ 4%	$1,737.19
Track maintenance, $565.00 per mo. × 12	6,780.00
Length of 4280 ft.	$8,517.19
$\$8{,}517.19 \times \frac{5280}{4280}$	$10,507.20 per mile

COST PER ANNUM CONCRETE ROADBED (With conduits)

$61,011.53, @ 4%	$2,440.46
Track maintenance, $90.00 per mo. × 12	1,080.00
Length of 4280 ft.	$3.520.46
$\$3{,}520.46 \times \frac{5280}{4280}$	$4,344.25 per mile

COST PER ANNUM CONCRETE ROADBED (Without conduits)

$56,423.53, @ 4%	$2,256.94
Track maintenance, $90.00 per mo. × 12	1,080.00
Length of 4280 ft.	$3,336.94
$\$3{,}336.94 \times \frac{5280}{4280}$	$4,117.78 per mile

This roadbed construction was designed and patented by Mr. Lincoln Bush, who was at the time Chief Engineer of the Delaware, Lackawanna and Western Railroad.

FIG. 142.—BIG MUDDY RIVER BRIDGE, ILL. CENTRAL R. R.

CHAPTER XVI.

TELEGRAPH POLES, POWER TRANSMISSION POLES AND TOWERS.

TELEGRAPH POLES.

Owing to the increasing scarcity and inferior quality of wood, which has heretofore been used exclusively for telegraph and trolley poles, engineers

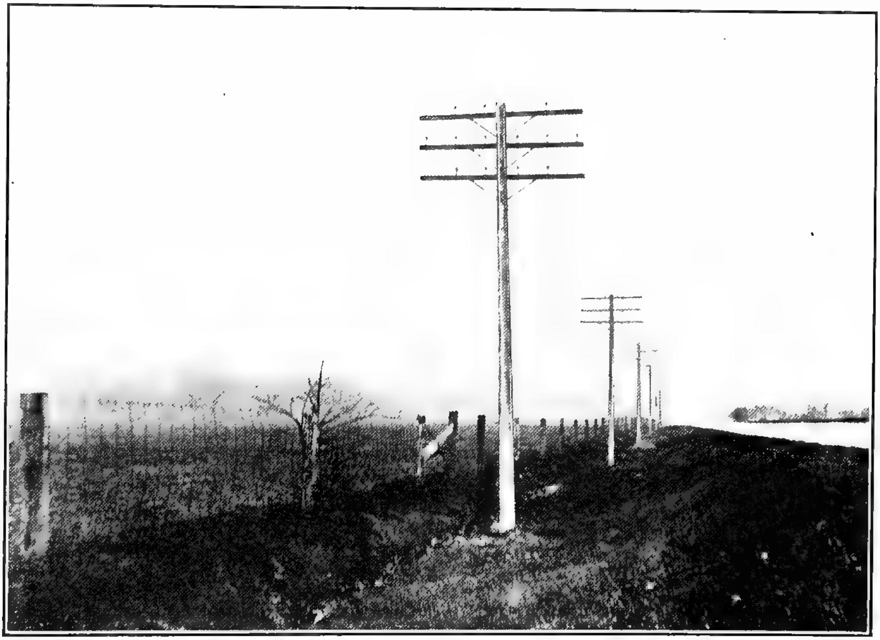


FIG. 143.—CONCRETE TELEGRAPH POLES, P., L. W. OF P.

have been experimenting with reinforced concrete for a number of years with the result that poles have been designed which are meeting the requirements in every way.

Among the advantages of the reinforcd concrete pole, the facts are that lines thus equipped have practically no trouble from lightning, the reinforcing rods apparently acting as conductors of electricity; that the pole requires no preservative or paint to protect it from the ravages of weather, as is the case with wood or steel; and that it is elastic enough to withstand all ordinary shocks.

That a reinforced concrete pole of economical dimensions possesses the requisite strength has been demonstrated both in this country and abroad by experiments* on concrete and wooden poles of the same sizes.

In 1907 Mr. Robert A. Cummings† made some comprehensive tests for the Pennsylvania lines west of Pittsburg on reinforced concrete and white cedar poles, which resulted in showing that the concrete pole was not only stronger than the wooden poles but also that, after breaking, the end was held in a

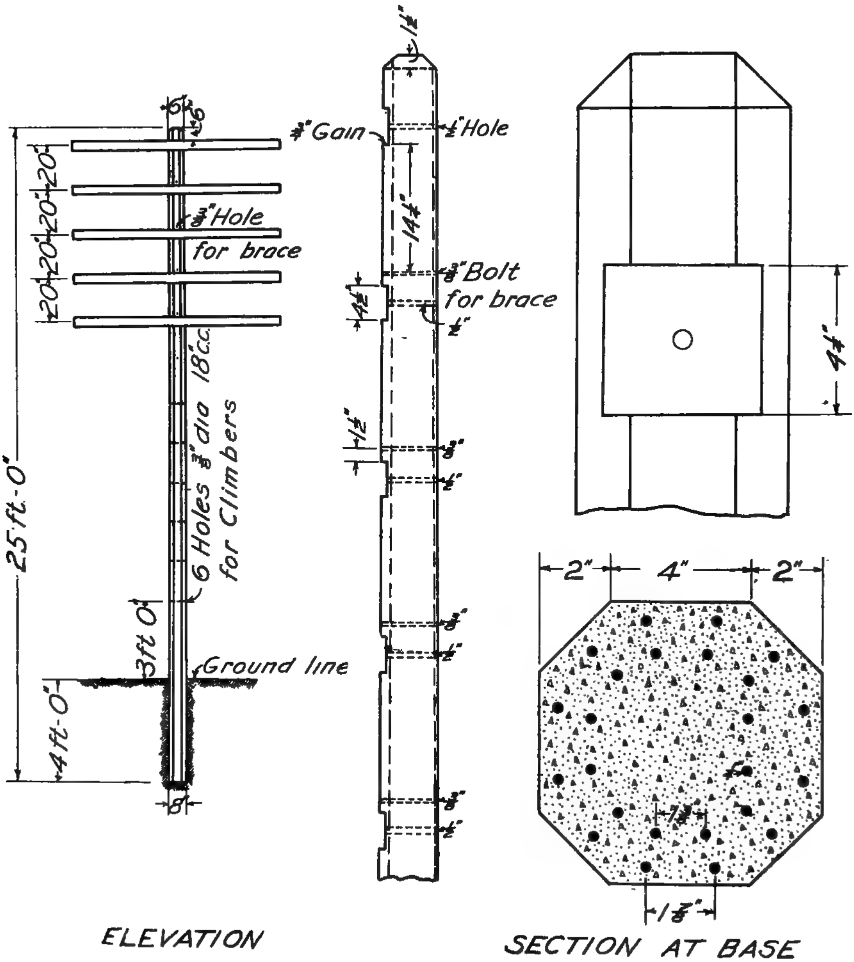


FIG. 144.—CONCRETE TELEGRAPH POLES, P., L. W. OF P.

*Cement Age, August, 1907, p. 84; Cement, July, 1903, p. 168; Concrete, March, 1907, p. 40.

†Cement Age, August, 1907, p. 84.

slightly inclined position by the reinforcement, while the wooden pole fractured completely and fell to the ground.

Mr. W. W. Bailey* made some very thorough tests in 1908 of reinforced concrete and of cedar poles 30 feet long and embedded 5 feet in the ground. Both poles were 7 inches at the top and 12 inches at the ground line. The concrete pole was reinforced with four 5/8-inch twisted steel rods bound together with No. 9 binding wire. With a horizontal pull at the top of 1,780 pounds, the concrete pole deflected 17 inches and broke from a horizontal pull of 7,200 pounds with a deflection of over 6 feet before falling, while the wooden

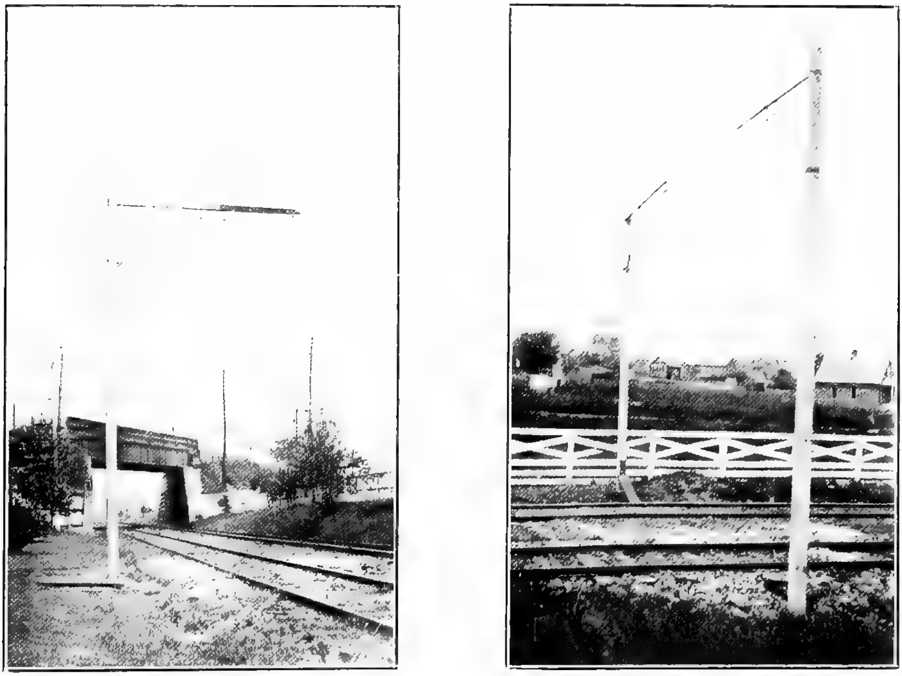


FIG. 145.—TICKLER POLES, N., C. & ST. L. RY.

pole, with a pull of 1,780 pounds, deflected 33 inches and broke at 2,200 pounds.

In general concrete poles are designed with a square section, with the corners chamfered off, tapering from bottom to top and with tapering reinforcement, thus meeting the condition of the decreasing strain, which is of course greatest at the ground line and decreases toward the top where the strain is applied. Aside from telegraph poles such as are described below, concrete has been used to good advantage in the construction of tickler poles, a successful type of which is described on page 191.

*Concrete Engineering, March, 1909, p. 67.

TELEGRAPH POLES, P., L. W. OF P.—The drawing in Fig. 144 shows the details of poles designed by Mr. F. M. Graham, Engineer, Maintenance of Way, which the Pittsburg, Ft. Wayne and Chicago division of the Pennsylvania Railroad are installing along their lines. These poles range in height from 25 to 34 feet and are 8 inches square at the bottom, tapering to 6 inches square at the top, with the corners chamfered two inches. The reinforcement consists of 24 ¼-inch wires running the full length of the poles. Holes are left in the poles for the brace and cross arm bolts and also for the climber steps. The poles are built at gravel pits along the line and a wet mixture of 1 cement to 3 sand to 3 of gravel is used. After the poles have cured, they are hauled out on cars to the point of erection where they are set four feet in the ground and bedded in stone screenings. The photograph in Fig. 143, page 187, shows these poles in actual service.

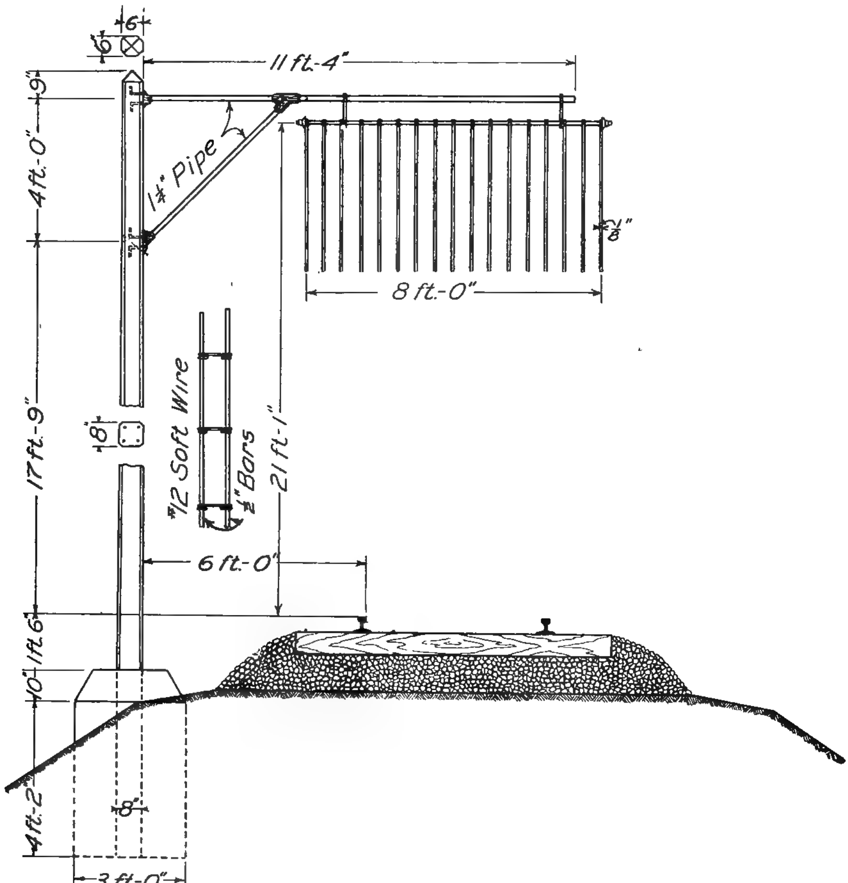


FIG. 146.—DETAILS OF TICKLER POLE, N., C. & ST. L. RY.

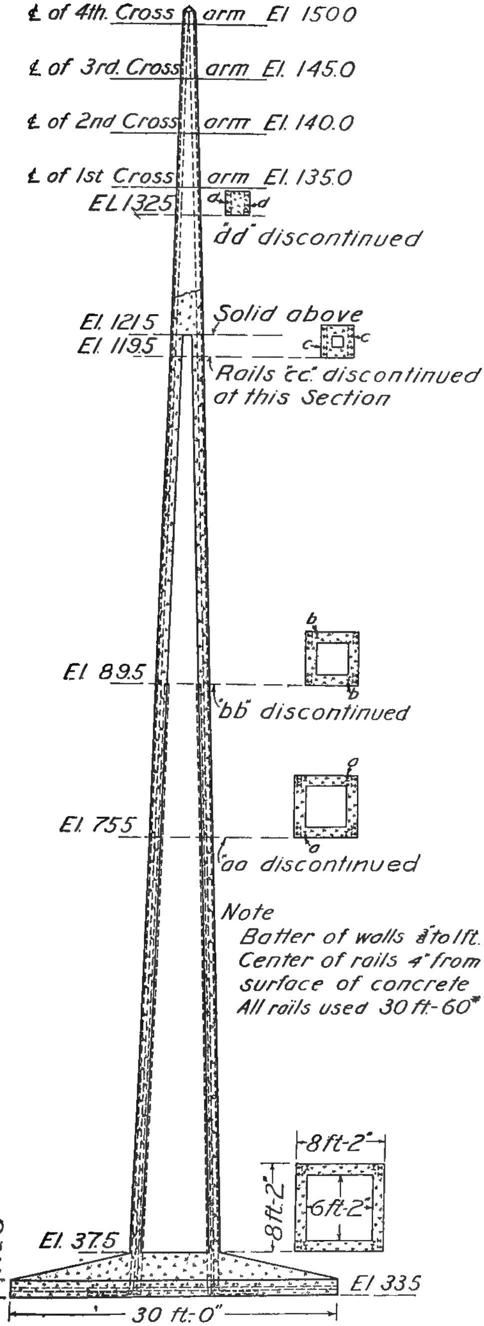


FIG. 147.—DETAILS OF CONSTRUCTION, BROWNSVILLE TRANSMISSION TOWERS.

TICKLER POLES, N., C. & St. L. RY.—In 1904 the Nashville, Chattanooga and St. Louis Railway, Mr. Hunter McDonald, Chief Engineer, erected four bridge warnings using concrete poles for supporting the warning straps or ticklers which have given such satisfaction that they have been adopted as standard for that purpose. These poles, the details of which are shown by the drawings in Fig. 146, and by the photographs in Fig. 145, are 8 inches square at the bottom and 6 inches square at the top, and are reinforced for the full length of 29 feet with four ½-inch round rods banded every foot with No. 12 soft wire. The ticklers on two of the poles are carried by cross-arms and braces of concrete cast with the pole, but since it was found that the concrete cross-arms were expensive as well as so heavy as to cause the pole to bend to an unsightly extent, gas pipe cross-arms were used instead and found satisfactory in combination with the concrete pole.

POWER TRANSMISSION POLES AND TOWERS.

In the long distance transmission of electrical energy from one point to another, it is necessary from an economical standpoint to use longer spans than wooden poles can safely carry. This condition led first to the adoption of steel structures which not only had the effect of increasing the initial cost and cost of maintenance, but also necessitated a wider right of way than single pole construction. To eliminate these disadvantages and at the same time obtain a pole of sufficient strength for long span construction engineers turned to reinforce concrete with the

result that poles have been designed which after several years of trial are proving entirely satisfactory.

In constructing concrete power transmission poles, both hollow and solid sections are employed. An example of the former type is the Brownsville tower described below, while the poles which the Lincoln Electric Light and Power Company* use to carry their wires over the old Welland Canal at St.

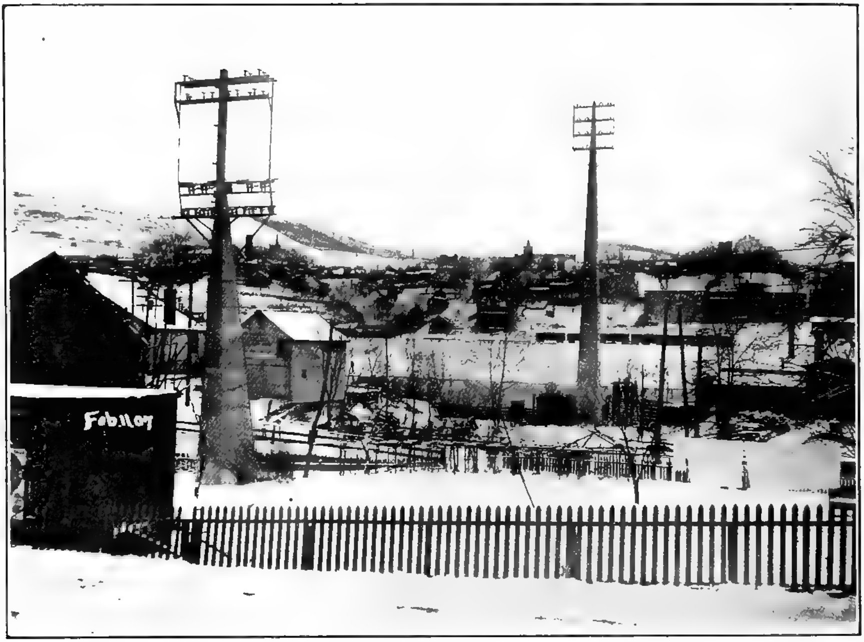


FIG. 148.—BROWNSVILLE TRANSMISSION TOWERS, WEST PENN. RAILWAYS CO.

Catherines, Ontario, are noteworthy examples of the latter type. These consist of reinforced concrete poles 150 feet high, 142 feet being above the ground. They are 31 inches square at the base and 11 inches square at the top and are reinforced with four 2½-inch round rods. The poles were made horizontally on the ground and raised into upright position by means of a pair of shear legs.

BROWNSVILLE TRANSMISSION TOWERS.—In the spring of 1907 the West Pennsylvania Railways Company was confronted with the problem of supporting a high potential power transmission line across the Monongahela River at Brownsville, Pa., a distance of 1,014 feet, and at the same time

*Transactions American Society Civil Engineers, Vol. LX., p. 160.

of keeping the cable 79½ feet above the low water mark, as required at that point by government regulations.

On the Brownsville side of the river no tower was necessary, as a firm anchorage could be obtained in the sub-station of the company. On the opposite side, where a tower was found necessary, it was decided to build a main tower, as close to the river as possible, designed to carry only the weight of the cables and the wind pressure against the cables and the tower itself, and 230 feet back of this a shorter tower designed to serve as an anchorage taking the direct strain of the main span.

In order that the main tower, the general details of design and construction of which are shown by the drawings in Fig. 147, might be designed for practically the wind stress alone, a special roller bearing saddle was devised for carrying the cables over the tower without a rigid connection. Both towers were designed as cantilever beams. The wind pressure considered in connection with the wind stress on the cables was taken as 40 pounds per square foot and the load on the cables as 20 pounds per square foot of projected ice-coated section. The cables themselves were treated as catenaries, the maximum unit load therefore being the resultant of the weight of the cable and the ice in a vertical direction and the wind load in a horizontal direction. With a maximum allowable sag of 36.6 feet and a minimum sag of 33.4 feet, there is assumed to be a pull of 122,000 pounds exerted on the anchorage tower at an average height of 38½ feet above its base.

The photograph in Fig. 148 shows both the main and the anchorage towers. The main tower, which rises 115 feet above its foundations, is pyramidal in form, being 8 feet 2 inches square at the base and 1 foot square at the top and has hollow walls 1 foot thick up to a point 84 feet above the base, where the section becomes solid. The anchor tower, which is of solid section throughout, is 4 feet by 10 feet at the base and batters up to a section 1 foot square at 41 feet 1 inch above the base, from which point it is of uniform section up to the full height of 55 feet.

In addition to the vertical reinforcing rails shown in Fig. 147, two spirals each of ⅜-inch cable, were wound 1 foot apart, thus making a 2-foot pitch for each cable. Gravel concrete mixed very wet was used throughout, the footing being mixed in the proportions of 1:2 ½:5 and the walls in the proportions of 1:2½:4.

Falsework 12 feet square was built for both towers sufficiently in advance of the wooden form so that both the forms and the 30-ft. reinforcing rails might be raised into position. For the exterior forms, three sections 6 feet high were made for each tower. One section was filled each day, and on the third day the bottom section was removed, cut down to the proper section and used above. Before filling the form, each was given a thin coat of motor

grease. The interior forms for the main tower consisted of hemlock sheathing backed up by 2 by 4 inch bracing and were left in the tower.

The concrete was mixed in a No. 1 mixer, driven by a 10-horse power belt connected electric motor and was hoisted to the required elevation by a friction hoist operated by a 7½ horse power single phase motor.

The towers were designed and constructed by the West Penn. Railways Company under the general direction of Mr. W. E. Moore, General Manager, and Mr. J. S. Jenks, Superintendent of Transmission, with Mr. F. W. Scheidenhelm, Structural Engineer, in direct charge of design and construction.

FIG. 149.—CONCRETE PROTECTION PIER, N. Y. C. & H. R. R. R.

CHAPTER XVII.

POSTS AND FENCES.

The growing scarcity and the increasing cost of suitable timber for posts has brought concrete into quite general use. Concrete posts possess the advantage over wooden ones not only of unlimited life, greater strength and resistance to the action of fire and decay, but also they present a more pleasing appearance.

As to the adaptability of the concrete post to railroad use, the committee appointed by the American Railway Engineering and Maintenance of Way Association* to investigate this subject reported to the annual convention at Chicago in March, 1909, in part as follows:

> "From observation of concrete fence posts your Committee considers that the concrete fence post will heave very little or not at all, as posts set from two to five years are at present in almost perfect alignment, and not a loose or broken post was found. They appear sufficiently strong for all practical purposes after being properly cured and set. The claim that concrete posts, reinforced with steel, form lightning protectors appears reasonable. They will, of course, resist the action of fire and decay. They will not float and cannot be displaced so easily as wood posts. On the other hand, concrete posts must be carefully handled in loading and unloading and well cured before using. Fence wire in contact with their surfaces should be well galvanized.
>
> "The concrete post is much heavier than the wood post and the cost of distributing is about 25 per cent greater.
>
> "It would seem that the concrete post is particularly adapted to railroad use. Most of the post machines are cheap and portable and the materials used are in daily use on all roads using concrete. The materials are cheap and easily obtained."

In regard to the various types and methods of making such posts the same committee after corresponding with over twenty manufacturers of posts and post-making machinery in the United States and Canada reported that:

> "A majority of these firms use or advise the use of Portland cement and gravel ranging from the size of sand to pebbles which will pass a wire

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*Bulletin No. 107, January, 1909, p. 323.

screen having meshes of from $\frac{1}{2}$ to 1 inch square. The ratio of cement and gravel is as 1 to 4. The methods of reinforcing and tamping concrete posts vary almost as much as those of fastening the fence wire to the posts. The machines are of various capacities and design—from the one post hand mold to the 'post per minute' power machine, with continuous mixer attachment. The average total cubic contents of the 7-foot post is 0.825 cubic feet, of the 8-foot post, 0.95 cubic feet. The weights vary from 65 pounds to 95 pounds, according to methods of manufacture and reinforcement used. Concrete posts retail for from 25 cents to 35 cents per post. End and gate posts are of about three times the volume and cost of intermediate posts. In section concrete posts vary from square or rectangular to triangular, half round and circular. Reinforcements are of wire, wood, strap steel, steel and wire truss, wood and wire truss, chain scrap strips and expanded metal. Fence wire fastenings are also of various forms, from the wire loop around the post to the patent staple encasement.

"All the posts observed taper from a smaller top to a larger base. Some have very wide concrete bases."

FENCE POSTS.*

Concrete fence posts are either constructed in advance and put in place after they have set sufficiently hard as not to be injured by handling or are moulded in place. The posts in Dellwood Park described on page 197 are examples of the former type of construction, while the posts along the Harlem division of the New York Central and Hudson River Railroad, described on page 197, exemplify the latter. Fig. 150 is a suggested design of forms for fence posts when constructed in advance. As will be seen from the sketch, the posts are made with every alternate post lying the opposite way, thus making one intermediate board serve as a side to two posts.

As stated in the excerpt from the committee report given above, there are a variety of means for fastening fence wire to the post. Two methods are illustrated in Fig. 150, one being by embedding in the concrete a piece of No. 12 copper wire, 12 inches long bent in half with the halves twisted together and with the ends projecting from the post about two inches, to which the fence wires are connected, while the other consists in leaving a hole in the concrete through which the fence wire can be strung. This is done by placing well greased round rods or wood dowels in the post forms at the desired spots and leaving them in the concrete about a day, when they can be readily removed. A very simple and satisfactory method is to use large galvanized

*Methods of making concrete posts are treated in "Concrete About the Home and on the Farm," published by The Atlas Portland Cement Company.

staples having their ends bent so as to hook into the concrete, while still another way is by bolting a galvanized iron strip to the post as was done in the case of the Dellwood Park posts described on page 197.

STANDARD CONCRETE FENCE POSTS, N. Y. C. & H. R. R. R.—Fig. 152 gives the details of design and construction of these posts while the photograph in Fig. 151 shows the forms in place preparatory to pouring the concrete.

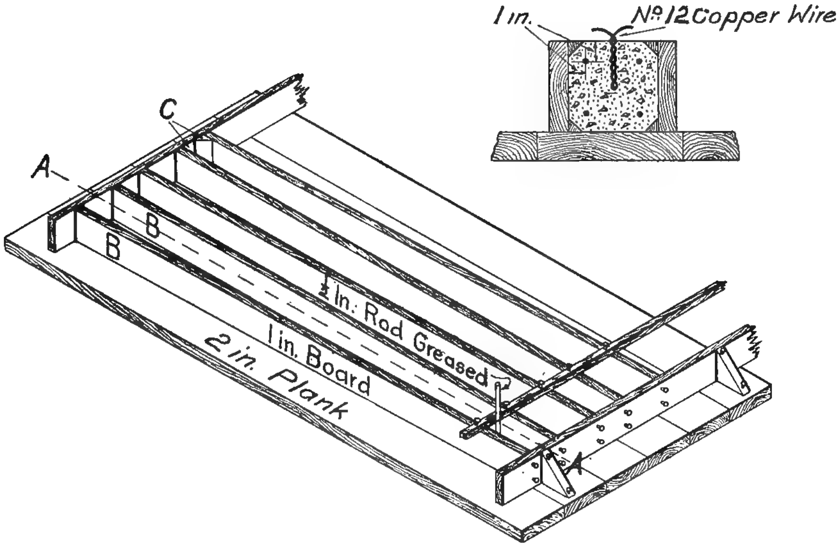

FIG. 150.—FORMS FOR FENCE POSTS.

The main posts are made of 1:3:6 concrete poured very wet, while the footings for the intermediate iron posts are mixed in the proportions of 1:4:7½. The forms are taken down 12 hours after being filled and the green concrete is floated with water and rubbed with a 1:2 cement and sand brick until the desired finish is attained.

In making these posts all the material is unloaded from a work train in advance of the job and a gang of six men do the work, two men excavating holes, two setting up the forms and two mixing and placing the concrete.

DELLWOOD PARK FENCE POSTS, C. & J. RY.—The posts shown in detail by the drawings in Fig. 154 and by the photograph in Fig. 153 were built by the Chicago and Joilet Electric Railway to support the galvanized iron woven wire fencing which encloses its amusement resort at Dellwood

FIG. 151.—FORMS IN PLACE, FENCE POSTS, N Y. C. & H. R. R. R.

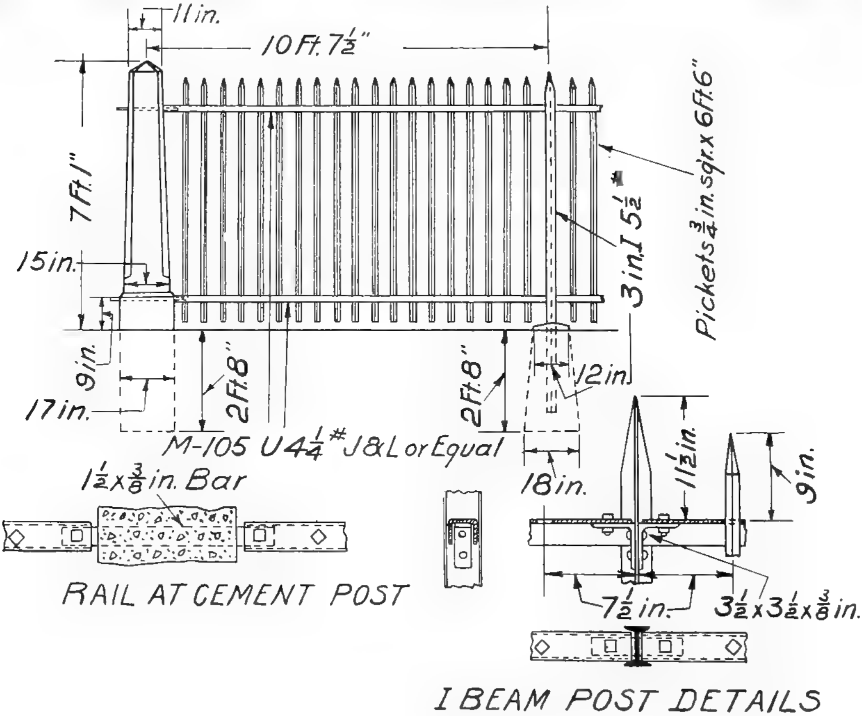

FIG. 152.—CONCRETE FENCE POSTS, N. Y. C. & H. R. R. R.

Park. They are spaced 10 feet on centers and are 7 and 9 feet long, 4 inches by 6 inches at the bottom and 4 inches by 4 inches at the top and are reinforced by four ¼-inch corrugated bars, one at each corner. The wire fencing is attached to them by a ⅛ by 1 inch galvanized iron strip bolted to each post through holes cast in the latter as it was made. Each post was cast in a separate wooden mould laid flat on a 2 by 8 inch plank, as shown in Fig. 154, and was allowed to season at least a month before being set in place. They were made of 1 part Atlas Portland Cement to 2 parts stone screenings, ranging from dust to ¼-inch pieces.

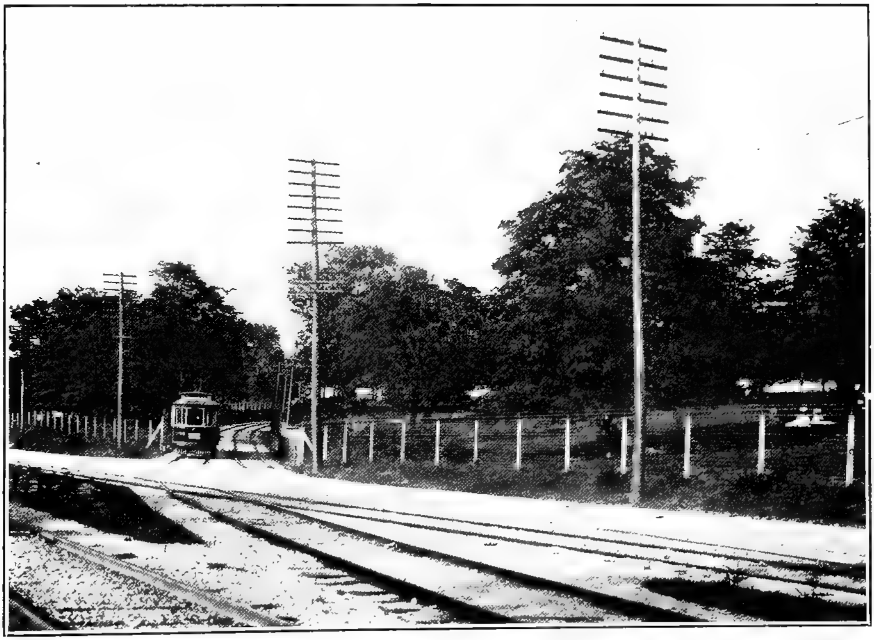

FIG. 153.—CONCRETE FENCE POSTS, DELLWOOD PARK.

The posts in the corners and at angles in the fence are made of larger sections than the others and are reinforced with a 2½ by 2½ by ¼ inch angle. A concrete brace is extended from each of these posts to the base of the adjoining regular posts which are set in concrete, all other posts being simply set in the ground and tamped around. Two men were engaged in making these posts and could produce about forty a day at an average cost of 65 cents for the 9-foot posts. The price is rather high owing to the expensive fittings, the cost of materials and methods of fastening the wire to post.

CONCRETE FENCE POSTS, B. & O. R. R.*—The Baltimore and Ohio Railroad concrete fence posts are of uniform size, 5 by 5 inches, and are reinforced with four ¼-inch rods. Wires are built into the back of the post pro-

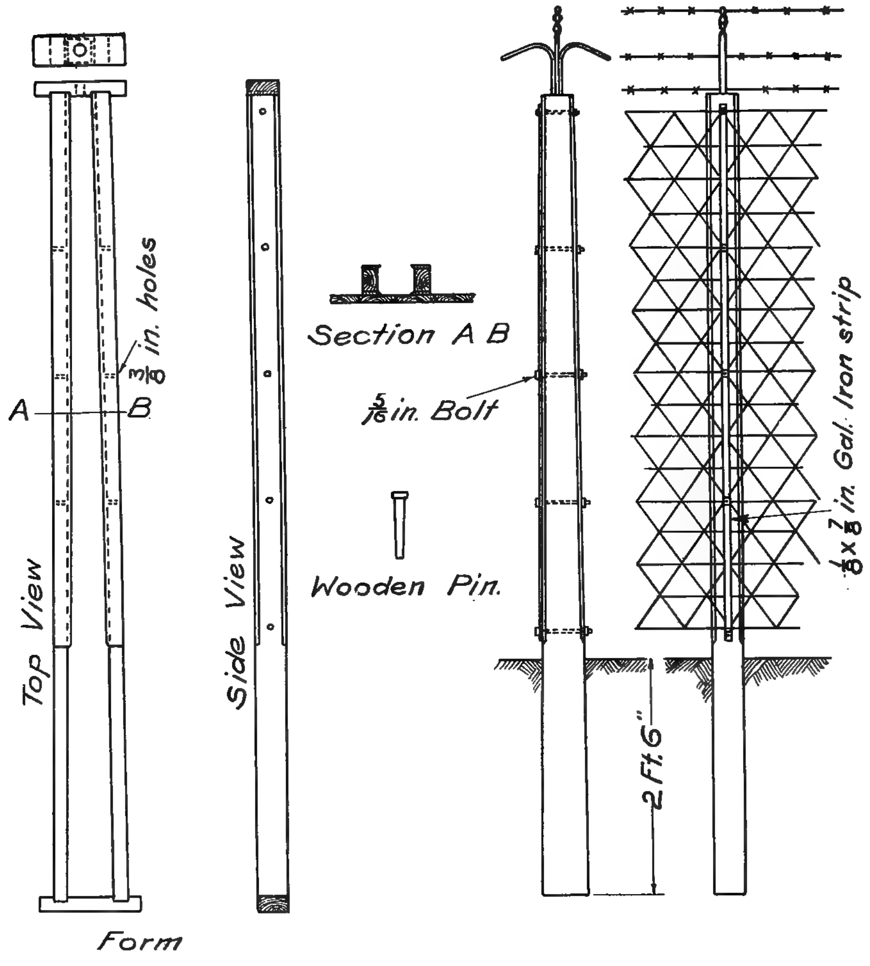

FIG. 154.—DETAILS OF CONSTRUCTION, DELLWOOD PARK FENCE POSTS.

jecting four inches, to which the woven wire fence is attached by means of pliers. These posts placed cost 44½ cents each.

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*Proceedings Association of Railway Superintendents of Bridges and Buildings, October, 1906, p. 69.

MILE POSTS.

Fig. 155 shows a type of concrete mile posts in use on the lines of the Chicago and Eastern Illinois Railroad that is meeting with success from a standpoint both of maintenance and permanence. As will be seen from the drawing the post is 8 by 8 inches square and 8 feet long, with 4 feet 6 inches above ground.

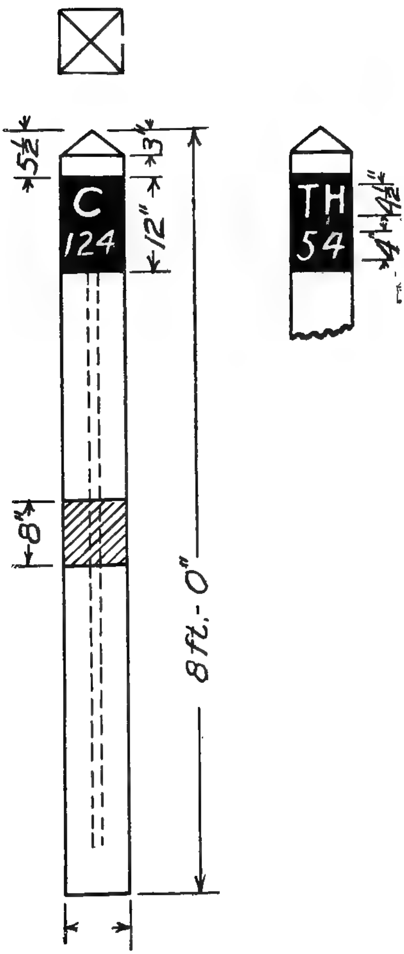


FIG. 155.—MILE POSTS, C. & E. I. R. R.

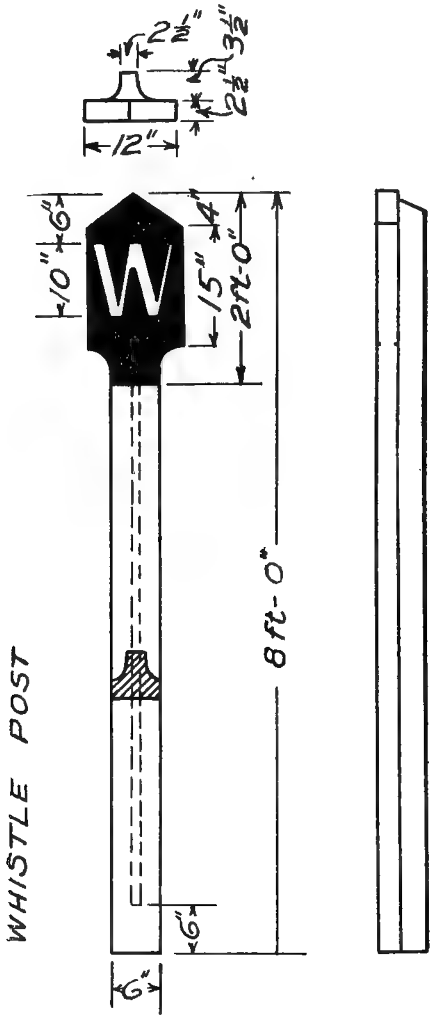


FIG. 156.—WHISTLE POSTS, C. & E. I. R. R.

The post, which weighs 498 pounds, is composed of concrete mixed in the proportions of 1 part cement to 1 part sand to 2 parts crushed stone and is reinforced for the entire length with one 1-inch corrugated bar placed in the center.

In moulding the posts the form is laid with the letters on the bottom, and the sides are plastered with mortar to a thickness of ½ inch before the ordinary concrete is put in.

The black face concrete of the lettered panel is colored with ¼ pound of lampblack mixed with 1 quart of cement in water, and is separated from the white concrete above and below by two recesses across the face of the post.

WHISTLE POSTS.

The posts in Fig. 156 represents a typical concrete whistle post in use on the Chicago and Eastern Illinois Railroad. Aside from the shape of the cross section, which is in the form of a T, the essential details of construction are the same as for the mile-posts on the same road described above. These posts are set at points 10 feet to the right of the track center and 2,000 feet each way from highway crossings.

The Lake Shore and Michigan Southern Railway use concrete whistle posts, made in moulds like blocks, which are 3½ inches thick, 12 inches wide and are set about 5½ feet above the ground. The letters and signs are cast right in the post and are painted black.

CLEARANCE POSTS.

Fig. 157 shows the design of concrete clearance posts on the Chicago and Eastern Illinois Railroad, which are set between main track and siding at a point where the distance between centers is 10 feet. These posts are 6 by 6 inches square and are reinforced for the entire length with either a ¾-inch scrap gas pipe, a ½-inch corrugated bar or four No. 9 wires.

PROPERTY LINE POSTS.

Fig. 158 represents the standard concrete property line posts which are set with the center on the property line and with the letters facing the track. These posts are made in triangular section and are reinforced for the entire length with a ¾-inch scrap gas pipe or a ½-inch corrugated bar or four No. 9 wires.

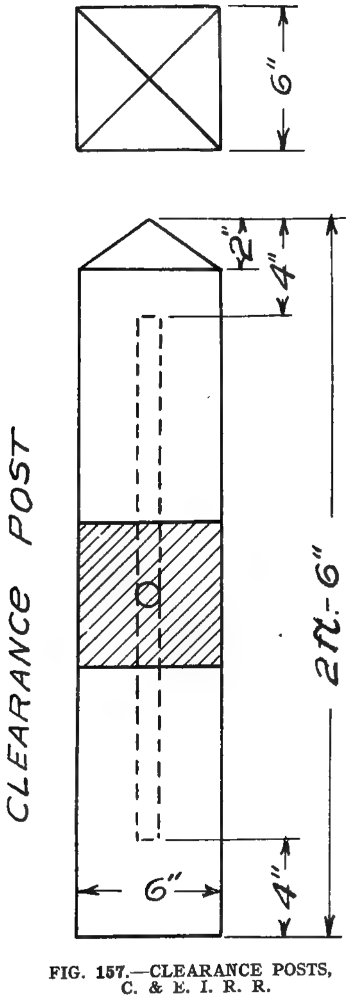


FIG. 157.—CLEARANCE POSTS, C. & E. I. R. R.

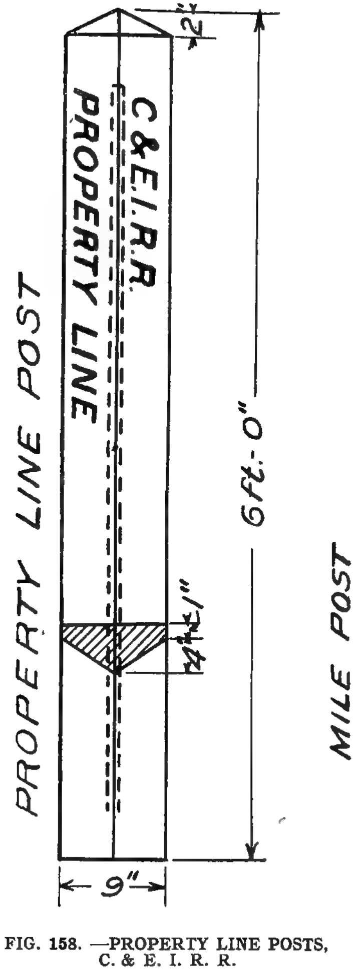


FIG. 158. —PROPERTY LINE POSTS, C. & E. I. R. R.

FENCES.

In places where a substantial fence is required ultimate economy, strength, durability and a pleasing appearance can be attained by the use of reinforced concrete. Two types of concrete fences have been tried with success, viz.: solid reinforced concrete and cement plaster on metal lath.

The solid type of fence generally consists of a vertical slab of reinforced concrete about 3 inches thick with a rounded moulding like a hand rail on the upper horizontal edge.

FIG. 159.—FENCE AT AVENUE J, B. R. T. CO.

PLATFORM FENCES.

An example of the plaster type of fence is described below:

PLATFORM FENCES, BROOKLYN RAPID TRANSIT CO.—These fences, which form guard railings on the outside and ends of the platforms described on page 106, Chapter VII., are 240 feet long, 4 feet 6 inches high, and 2 inches thick and are surmounted by a railing 4⅝ inches high and 5 inches wide. The drawings in Fig. 160 show the essential details of design and construction while the photograph in Fig. 159 shows the fence at Avenue J Station.

The reinforcement consists of metal lath of No. 28 gauge and is carried in continuous sheets through the entire length of the fence, except at expansion joints. The posts, which are 10 feet on centers, are reinforced with four ½-inch rods set deep in the concrete platform and the railing has two ⅜-inch rods running longitudinally with a strip of lath laid horizontally. The posts are formed by two short pieces of lath put in the shape of channels and placed around the reinforcing rods, one channel being on each side of the reinforced sheet of the panels.

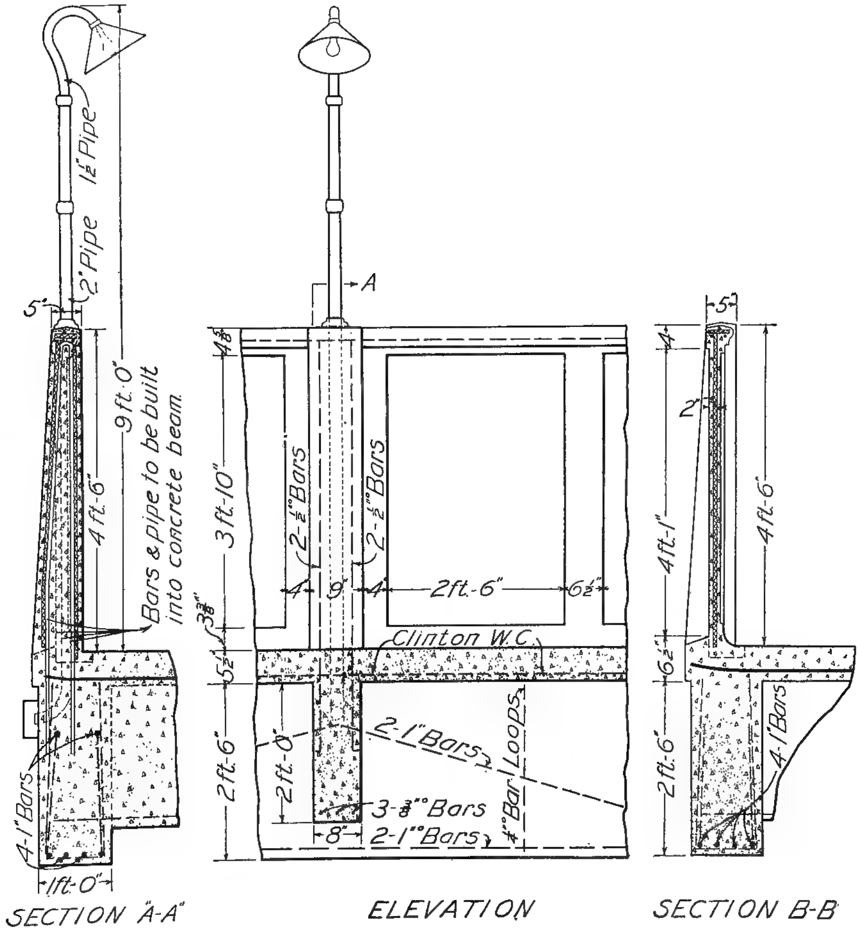
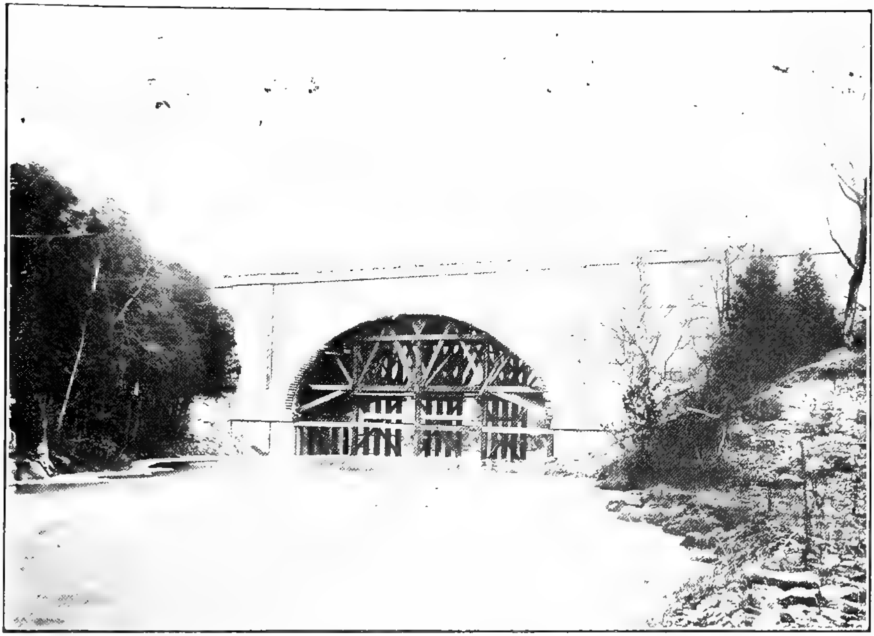


FIG. 160.—DETAILS OF CONSTRUCTION, PLATFORM FENCE, B. R. T. CO.

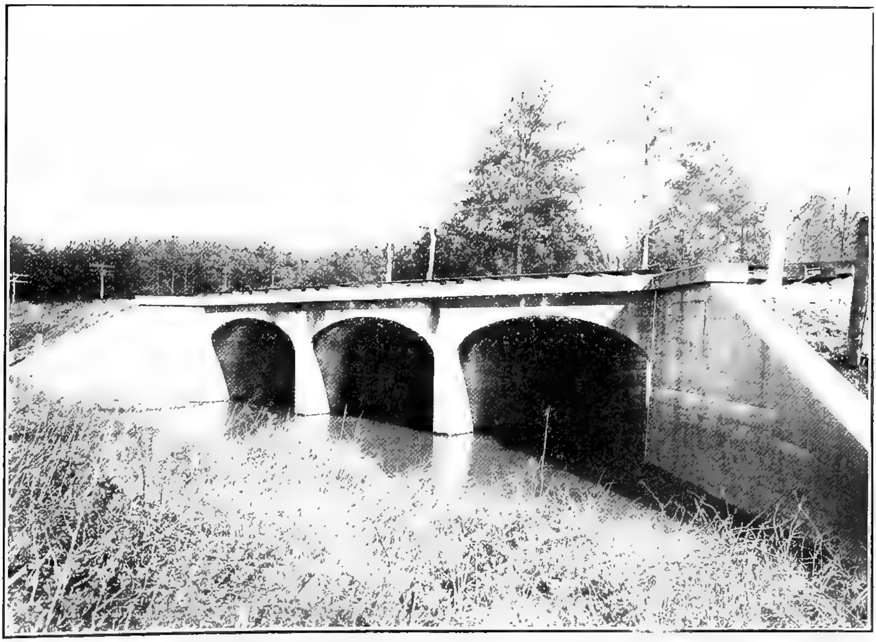
In constructing the fences the lath was held in place by 1-inch angle studding supported at the top by a 2 x 4 inch horizontal, braced to the platform. The scratch coat consisted of dry mixed 1:2 Atlas Portland Cement with an addition of 6 per cent. of hydrated lime and the finish coat was made of 1 part Atlas Portland Cement and 2 parts sand.

The lath reinforcing was erected by the Truss Metal Lath Co., New York, sub-contractors of Thos. G. Carlin, who had the general contract for the work under the supervision of the Brooklyn Rapid Transit Co., Mr. W. S. Menden, Chief Engineer.

FIG. 161.—MASKED TRUSS, 56TH STREET, NEW YORK, N. Y. C. & H. R. R. R.

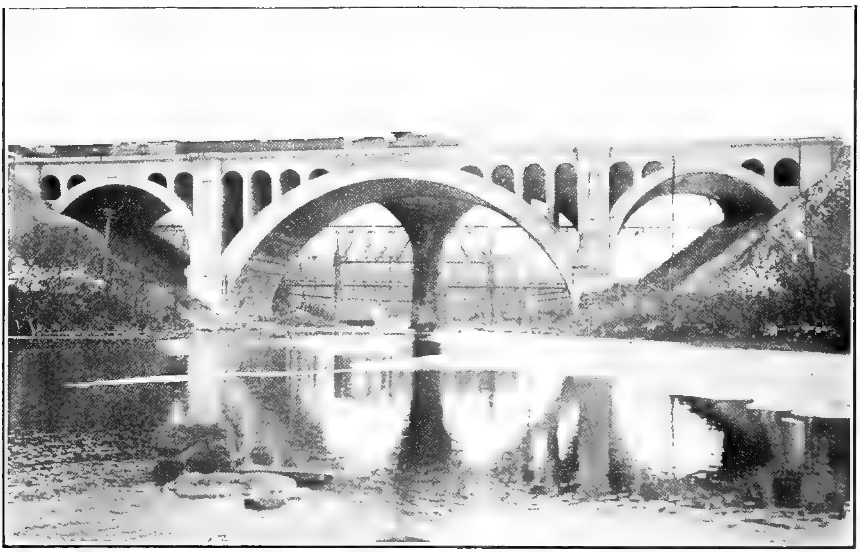


BRIDGE U 44, C., M. & ST. P. RY.



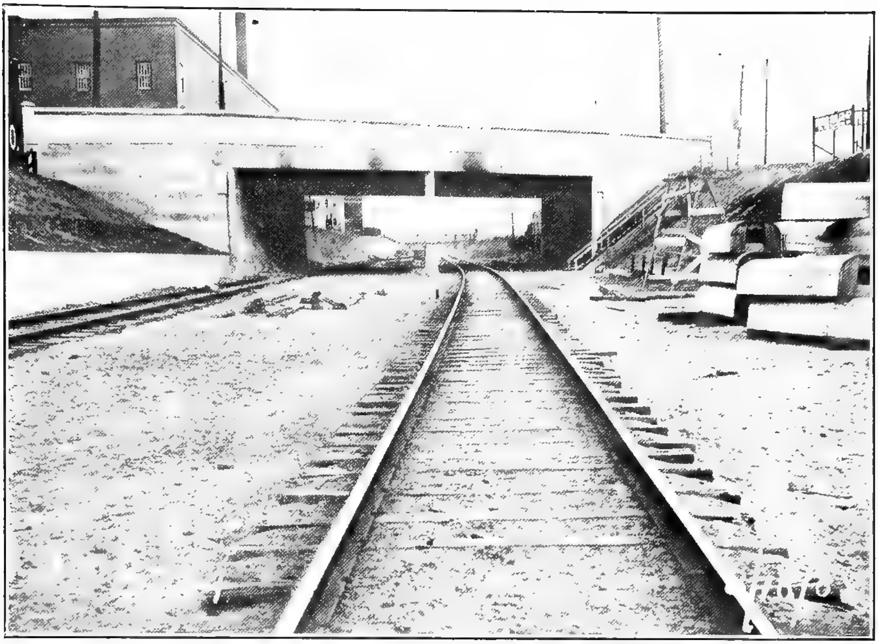
TRIPLE ARCH BRIDGE, ILL. CENTRAL R. R.

CHUTE FOR DEPOSITING CONCRETE, PAINSVILLE BRIDGE.

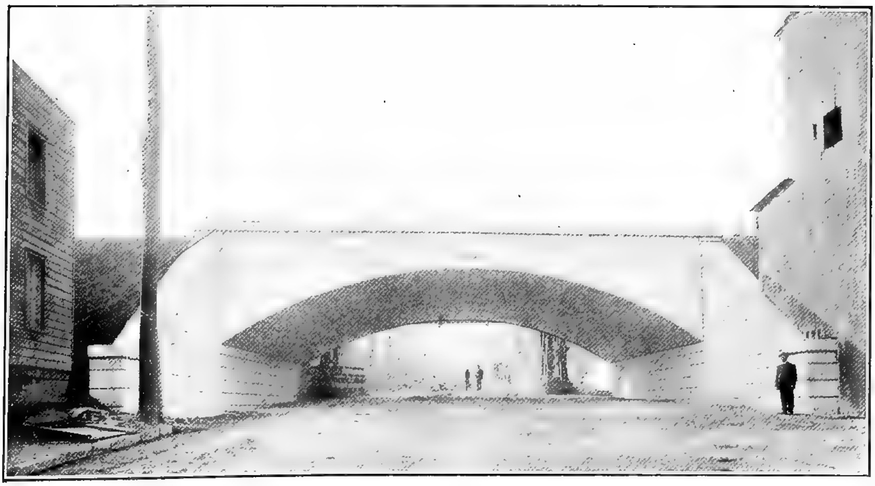


FOUR-TRACK REINFORCED CONCRETE ARCH OVER GRAND RIVER, PAINSVILLE, OHIO, LAKE SHORE & MICHIGAN SOUTHERN RY.

Span of center arch, **160** ft. **0** in. Total length of bridge, **382** ft. **0** in. Rise of center arch, **58 ft. 3 in. Tota** width of bridge, **65 ft. 0 in.** Span of each end arch, **70** ft. **0** in. Cubic yards of concrete, **25,150.**



OVERHEAD HIGHWAY BRIDGE, L. I. R. R.

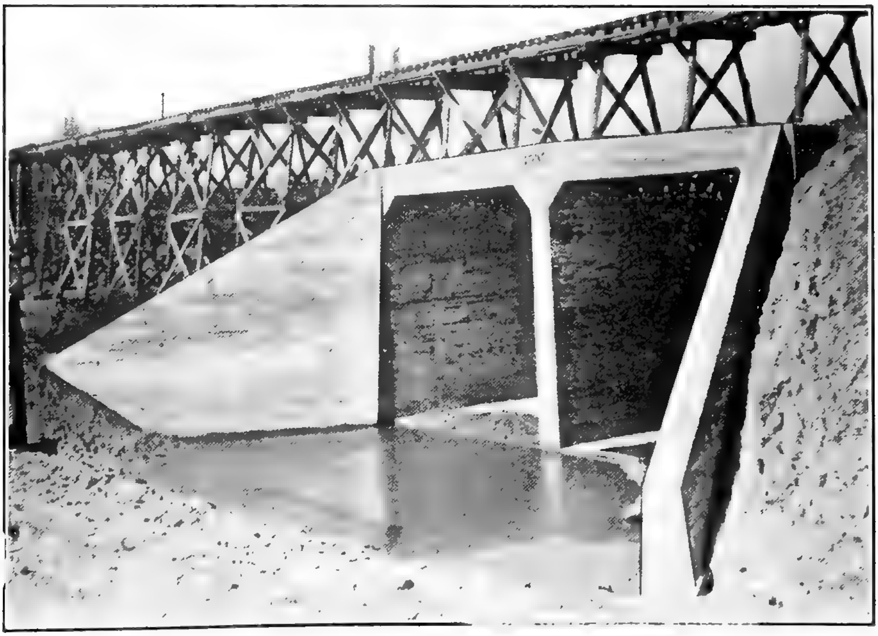


ARCH BRIDGE, SCHENECTADY, N. Y., N. Y. C. & H. R. R. R.

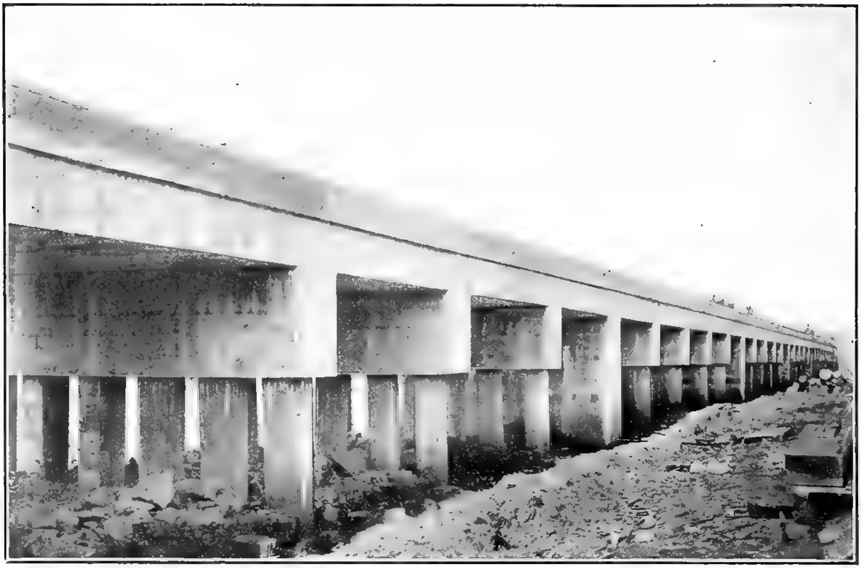
GUILFORD ARCH BRIDGE, BIG FOUR RY.

WINNIPEG VIADUCT, CANADIAN PACIFIC R. R.

CULVERT UNDER LOUISVILLE & NASHVILLE R. R. FREIGHT DEPOT, KNOXVILLE, TENN.



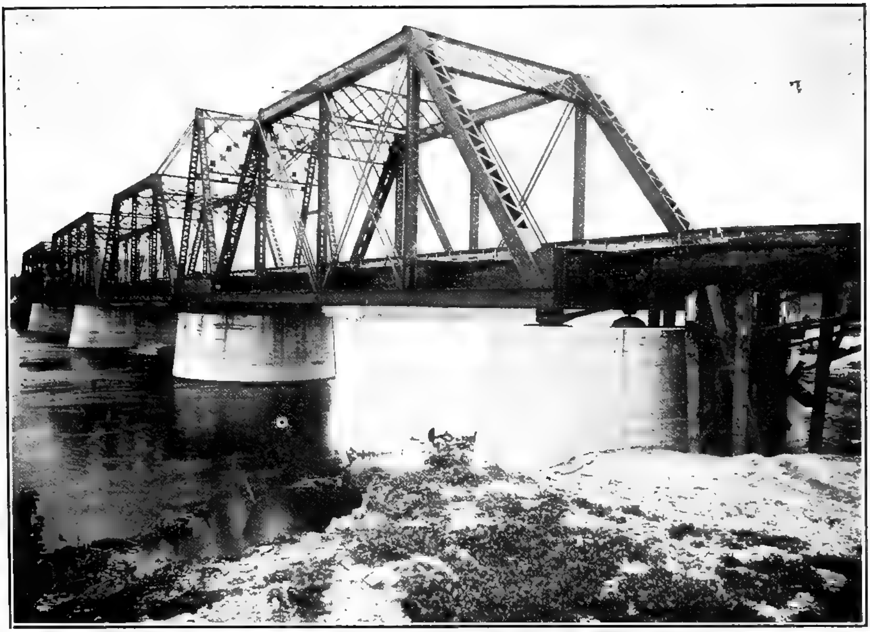
DOUBLE BOX CULVERT, C., B. & Q. R



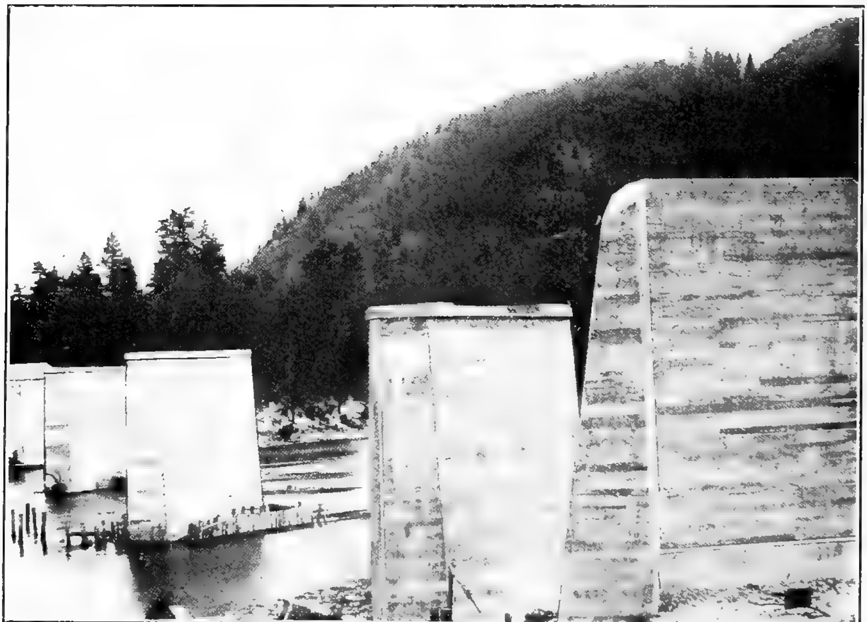
PILE TRESTLE OVER SALT RIVER, C., B. & Q. R. R.

NARROW GAUGE TRESTLE, CATSKILL MOUNTAINS, OTIS R. R. CO.

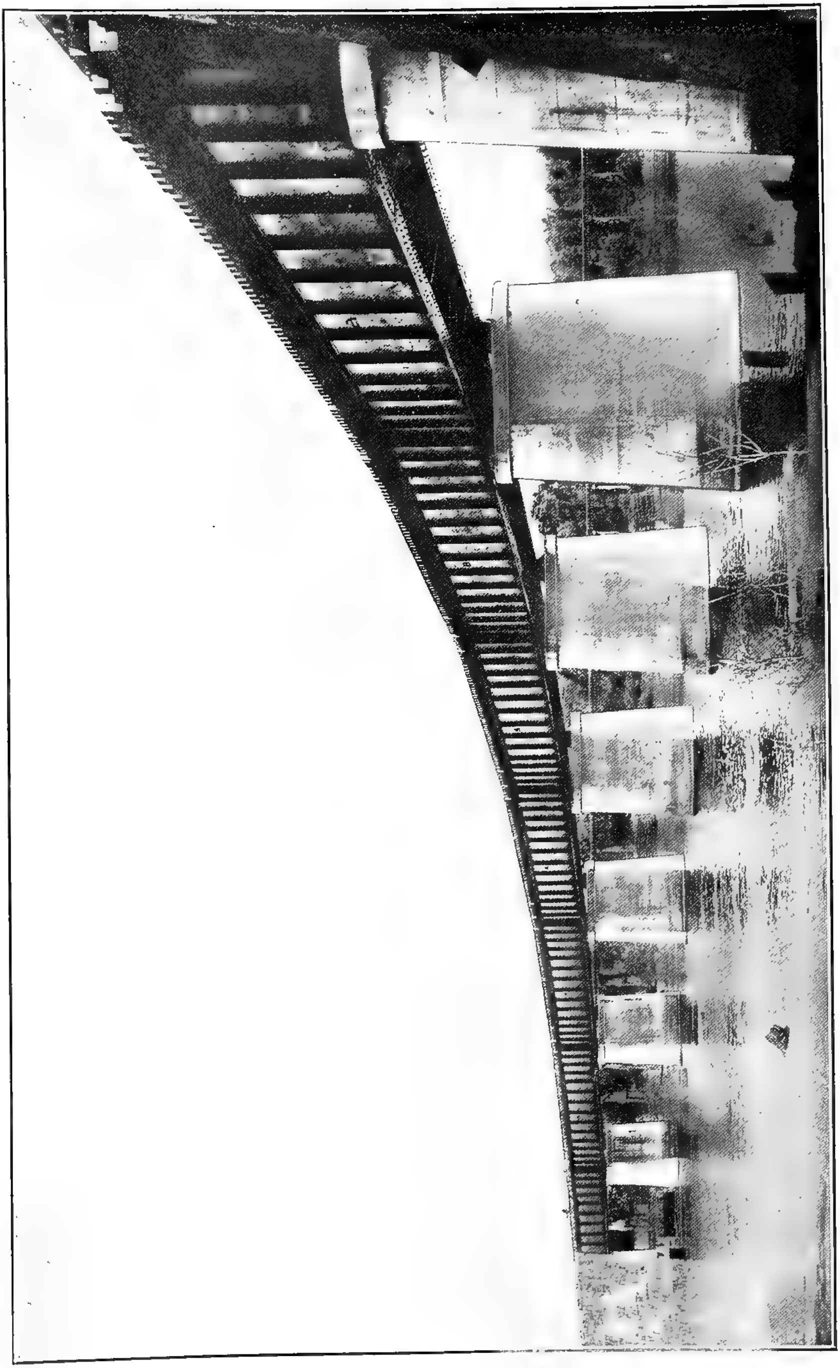
REINFORCED CONCRETE ABUTMENTS, CAHABA RIVER CROSSING, ATLANTA, BIRMINGHAM AND ATLANTIC R. R.
Height from the base to the top of the parapet, **61** ft. **6** ins.



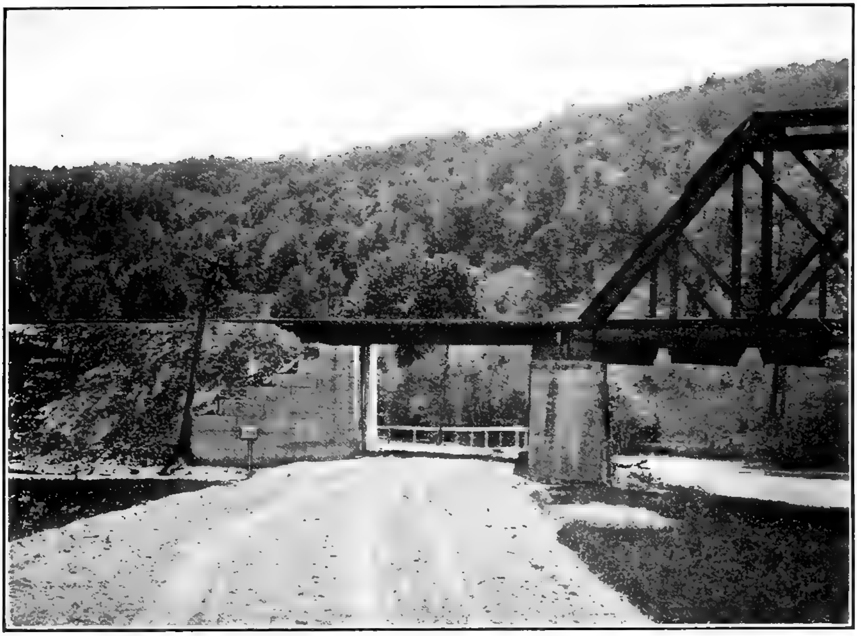
PIERS, GRAND RIVER BRIDGE, PERE MARQUETTE R.R.



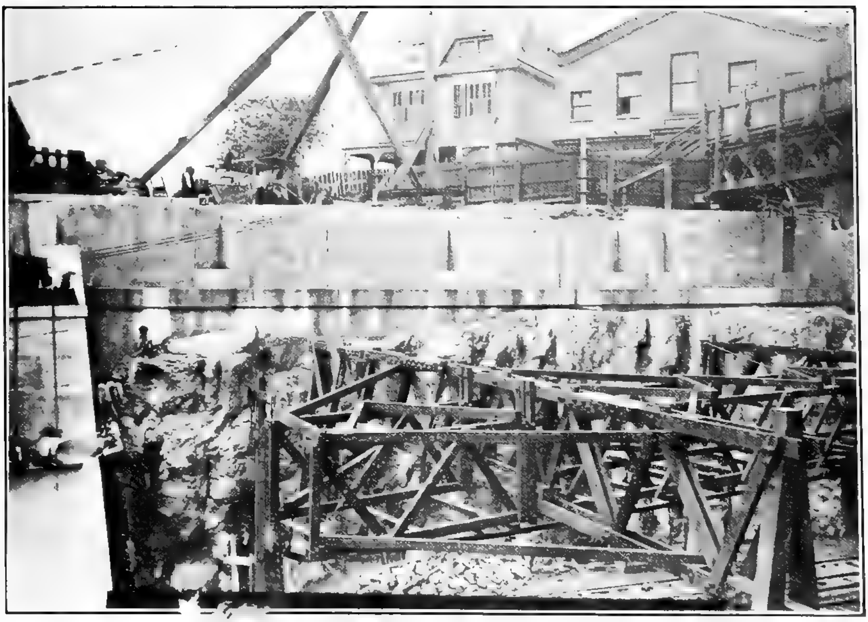
PIERS, AT FOURTH CROSSING, MISSOULA RIVER, N. P. RY.



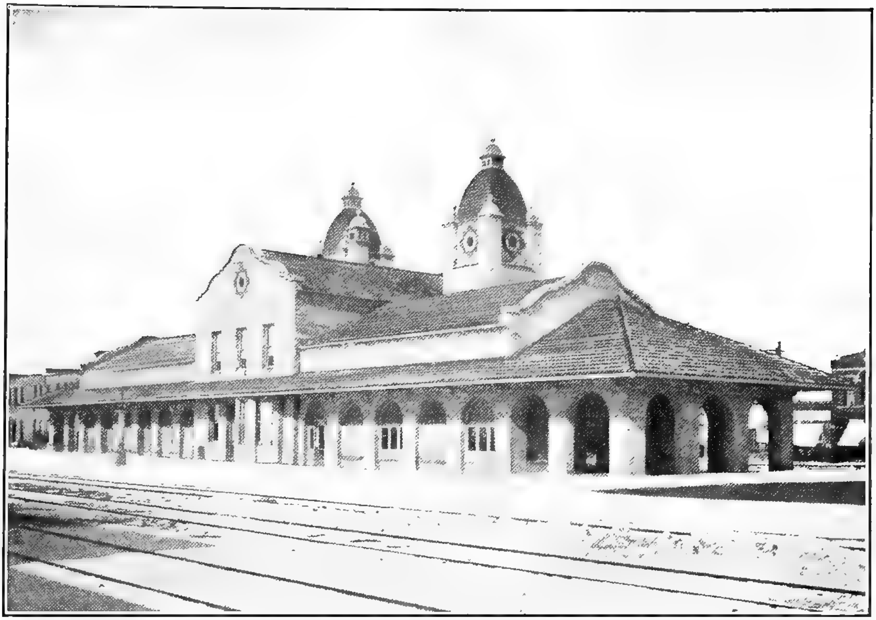
PIERS, SOUTH LEG, DAVENPORT "Y" BRIDGE, C., M. & ST. P. RY.



ABUTMENT AND PIER, BROWNS MILLS, VT., VERMONT CENTRAL R. R.

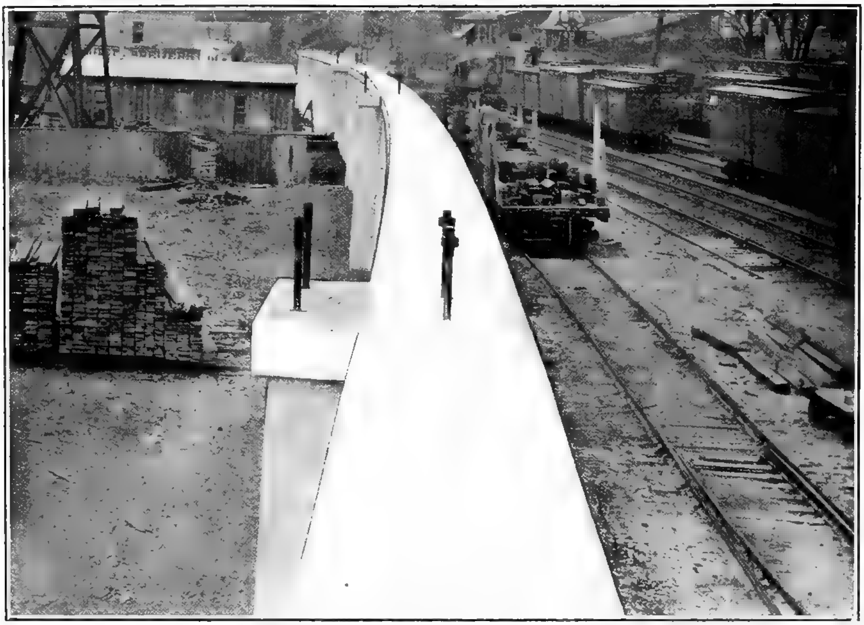


ABUTMENT FOR MOTT AVE. BRIDGE, N. Y. C. & H. R. R. R.

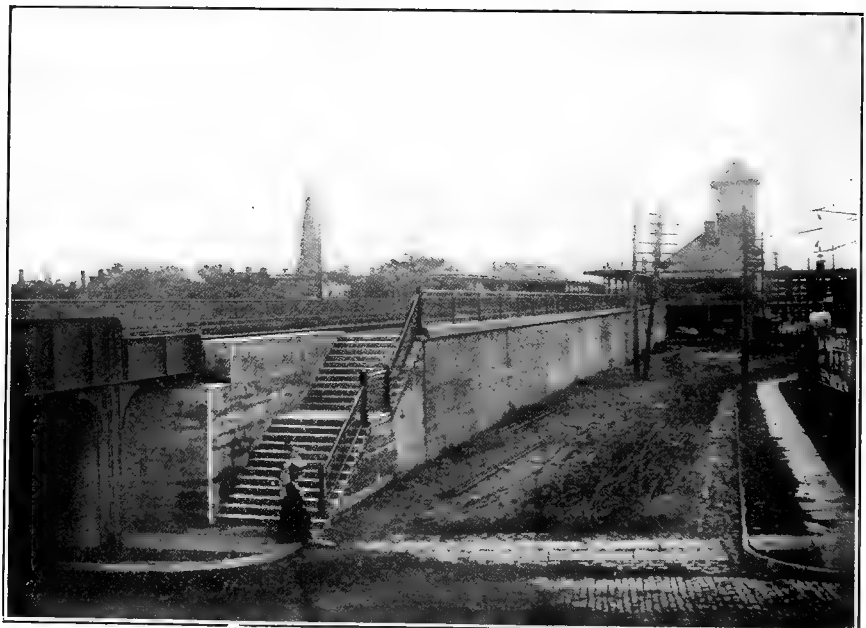


BISMARK, N. D., DEPOT, NORTHERN PACIFIC RY.

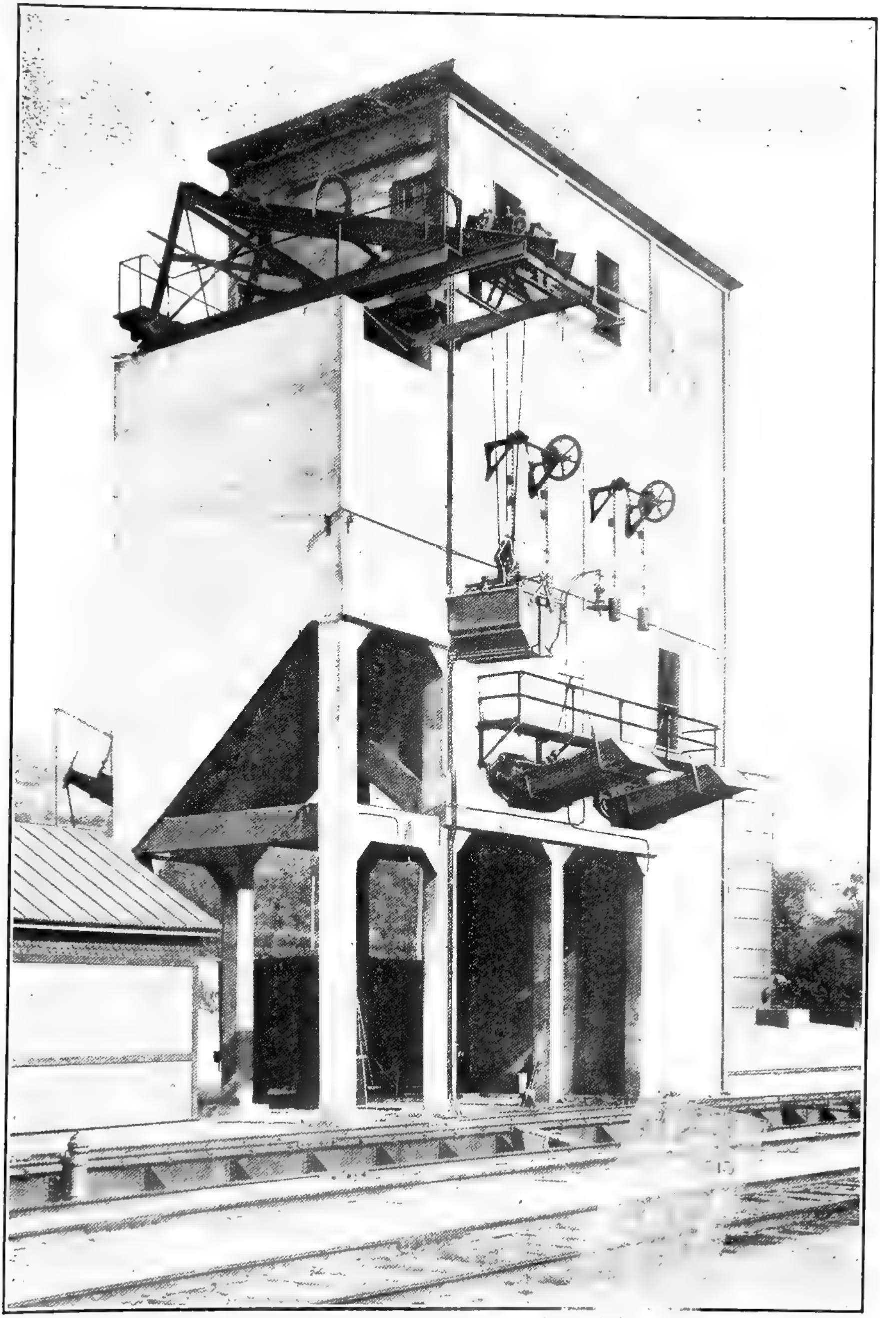
SANTA BARBARA, CAL., STATION, SOUTHERN PACIFIC RY.



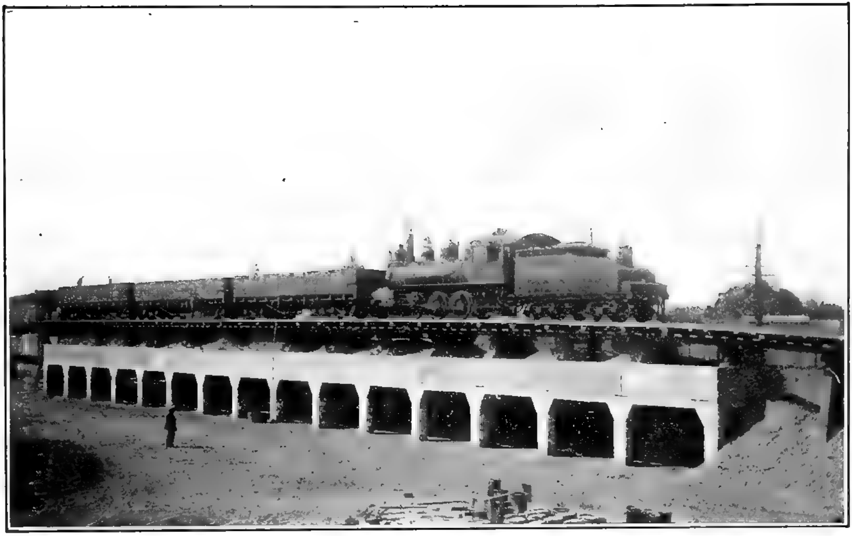
YONKERS IMP. RETAINING WALL BEFORE FILLING, N. Y. C. & H. R. R. R.



RETAINING WALL, D., L. & W. R. R. TRACK ELEVATION, NEWARK, N. J.



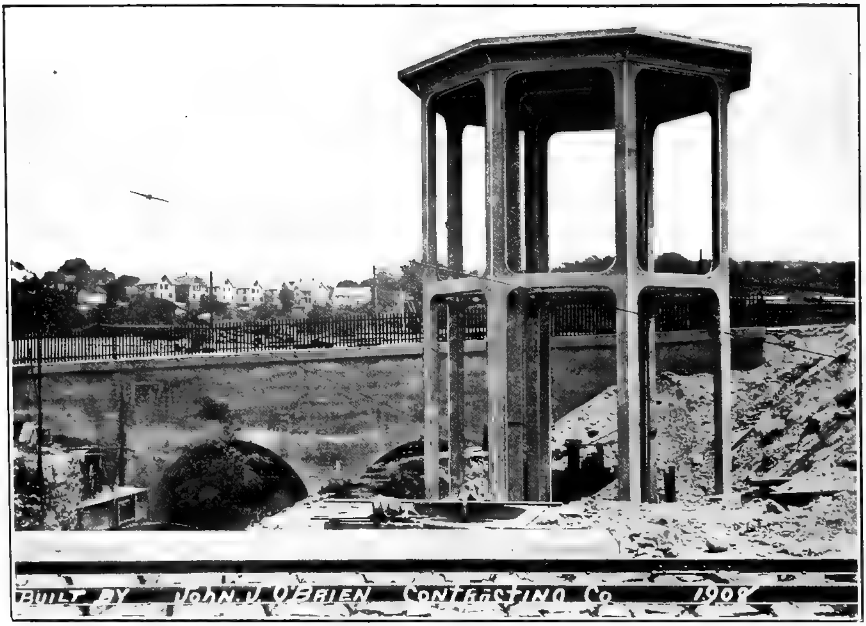
COALING STATION, POLLOCK, PA., PITTSBURG & LAKE ERIE R. R.



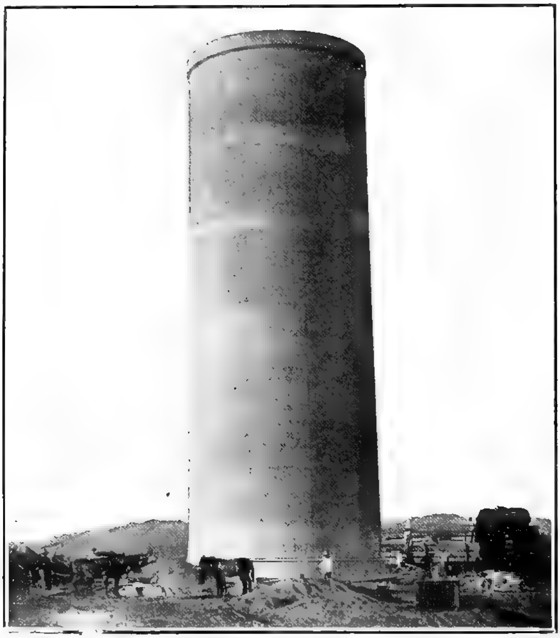
CRUSHED STONE HANDLING TRESTLE, SPRINGFIELD, MASS.

RETAIL COAL POCKET, MURRAY HILL, N. J., D. L. & W. R. R.

ANTHRACITE SCREENINGS POCKET, NEWARK, N. J. D. L. & W. R. R.

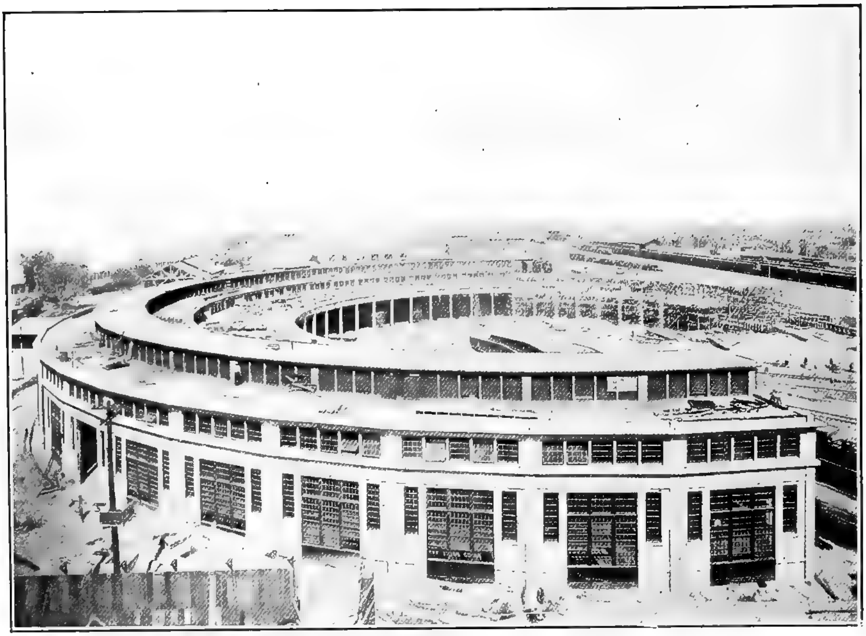


SUPPORT FOR WATER TANK, WATERBURY, CONN., N. Y., N. H. & H. R. R.

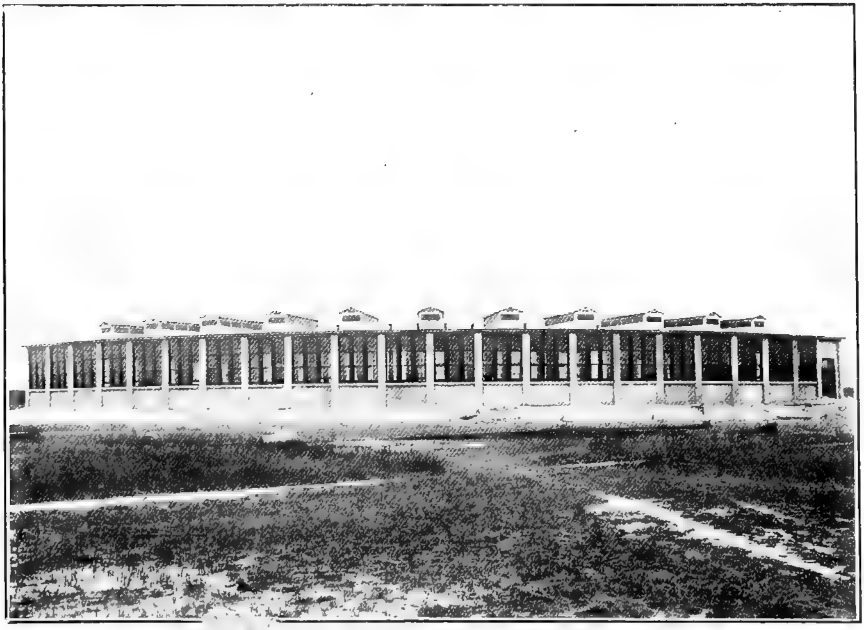

480,000-GALLON WATER TOWER, CANANEA, YAQUIS & PACIFIC R. R.

BAKERSFIELD, CAL., ROUNDHOUSE, A., T. & ST. F. RY.

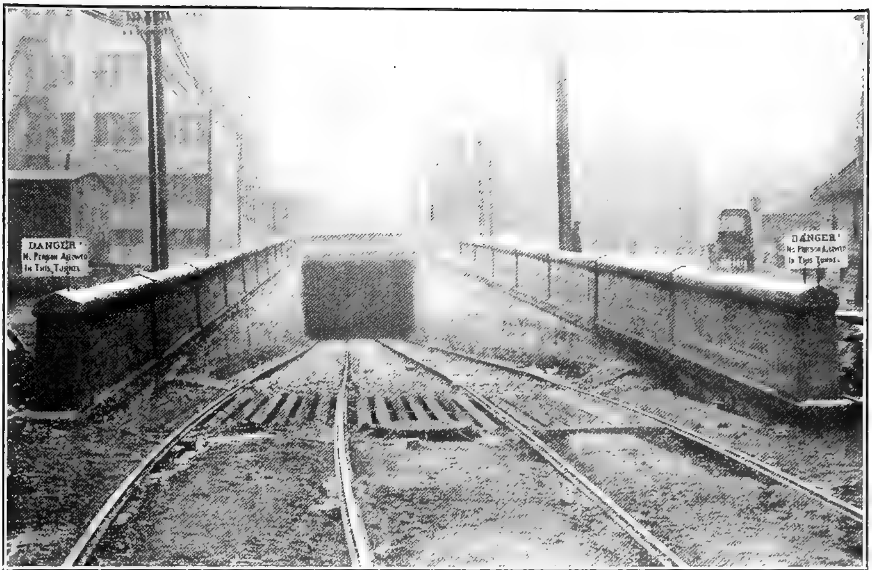
AMERICAN MALTING CO. ELEVATOR, BUFFALO, N. Y.



SAN BERNARDINO ROUNDHOUSE, A., T. & ST. F. RY.

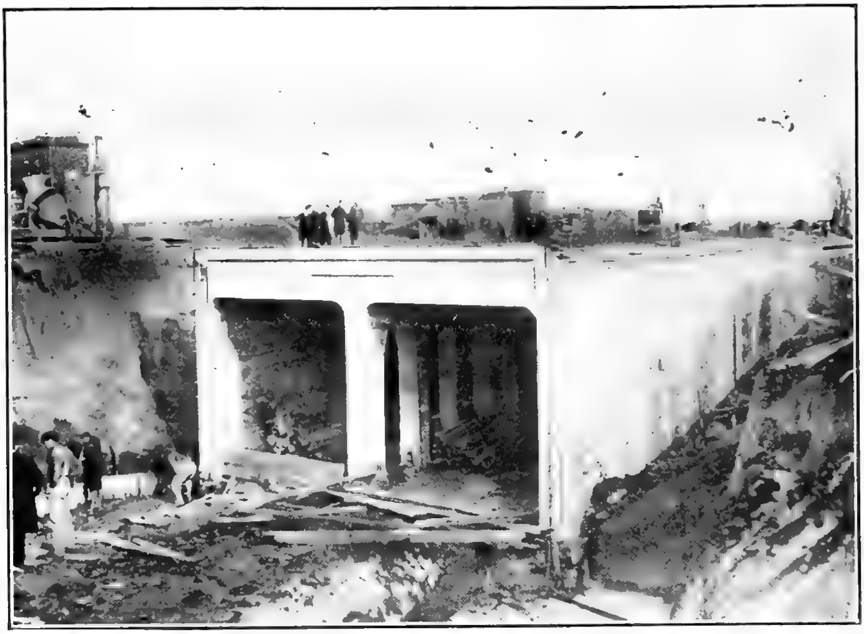


BUFFALO ROUNDHOUSE, LEHIGH VALLEY R. R.



PORTAL 8TH STREET TUNNEL, KANSAS CITY, MO.

INTERIOR 8TH STREET TUNNEL, KANSAS CITY, MO.



GALESBURG SUBWAY, C., B. & Q. R. R.

ENTRANCE OF TUNNEL, WEEHAWKEN, N. J., WEST SHORE R. R.

DUNTON INSPECTION SHED, L. I. R R.

PORTABLE SUB-STATION, L. I. R. R.

... ..N STORAGE BUILDING, C., M. & ST. P. RY.